Vol. V

EXHIBITS

TRANSCRIPT OF RECORD

Supreme Court of the United States

OCTOBER TERM, 1942

No. 369

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA, PETITIONER,

vs.

THE UNITED STATES

No. 373

THE UNITED STATES, PETITIONER,

vs.

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA

ON WRITS OF CERTIORARI TO THE COURT OF CLAIMS

PETITIONS FOR CERTIORARI FILED {SEPTEMBER 2, 1942. / SEPTEMBER 3, 1942.

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[fol. 3016] DEFENDANT'S EXHIBIT L-1

The Electrician, London, February 21, 1890

Problems in the Physics of an Electric Lamp[1]

By Prof. J. A. Fleming, M.A., D.SC., M.R.I.

(Concluded from page 395.)

At this stage it will perhaps be most convenient to outline briefly the beginnings of a theory proposed to reconcile these facts, and leave you to judge how far the subsequent experiments confirm this hypothesis. The theory very briefly is as follows: From all parts of the incandescent carbon loop, but chiefly from the negative leg, carbon molecules are being projected which carry with them, or are charged with, negative electricity. I will in a few moments make a suggestion to you which may point to a possible hypothesis on the manner in which the molecules acquire this negative charge. Supposing this, however, to be the case, and that the bulb is filled with these negatively charged molecules, what would be the result of introducing into their midst a conductor such as this middle metal plate which is charged positively? Obviously, they would all be attracted to it and discharge against it. Suppose the positive charge of this conductor to be continually renewed, and the negatively-charged molecules continually supplied, which conditions can be obtained by connecting the middle plate to the positive electrode of the lamp, the obvious result will be to produce a current of electricity flowing through the wire or galvanometer, by means of which this middle plate is connected to the positive electrode of the lamp. If, however,

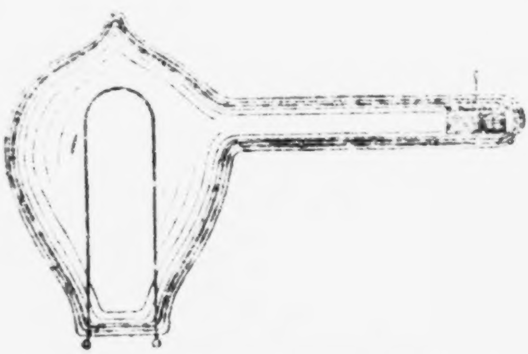

Fig. 8. Collecting plate placed at end of tube 18 in. in length, opening out of bulb.

[1] A discourse delivered at the Royal Institution on Friday evening, February 14, 1890.

the middle plate is connected to the negative electrode of the lamp, the negatively-charged molecules can give up no charge to it, and produce no current in the interpolated galvanometer. We see that on this assumption the effect must necessarily be diminished by any arrangement which prevents these negatively-charged molecules from *d*eing shot off the negative leg or from striking against the middle plate. Another obvious corollary from this theory is that the "Edison effect" should be annihilated if the metal collecting plate is placed at a distance from the negative leg much greater than the mean free path of the molecules.

Here are some experiments which confirm this deduction. In this bulb (Fig. 8) the metal collecting plate, which is to be connected through the galvanometer with the positive [fol. 3017] terminal of the lamp, is placed at the end of a long tube opening out of and forming part of the bulb. We find the "Edison effect" is entirely absent, and that the galvanometer current is zero. We have, as it were, placed our target at such a distance that the longest range molecular bullets cannot hit it, or, at least, but very few of them do so. Here again is a lamp in which the plate is placed at the extremity of a tube opening out of the bulb, but bent at right angles (Fig. 9). We find in this case, as first discovered by Mr. Preece, that there is no "Edison effect." Our molecular marksman cannot shoot round a corner. None of the negatively charged molecules can reach the plate, although that plate is placed at a distance not greater than would suffice to produce the effect if the bend were straightened out. Following out our hypothesis into its consequences would lead us to conclude that the material of which the plate is made is without influence on the result, and this is found to be the case. Many of the foregoing facts were established by Mr. Preece as far back as 1885, and I have myself abundantly confirmed his results.

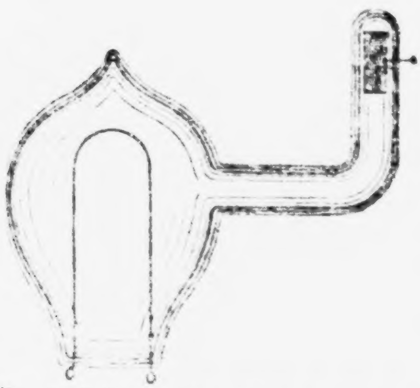

Fig. 9.—Collecting plate placed at end of a bent tube opening out of bulb.

We should expect also to find that the larger we make our plate, and the nearer we bring it to the negative leg of the carbon, the

greater will be the current produced in a circuit connecting this plate to the positive terminal of the lamp. I have before me a lamp with a large plate placed very near the negative leg of the carbon of a lamp, and we find that we can collect enough current from these molecular charges to work a telegraph relay and ring an electric bell. The current which is now working this relay is made up of the charges collected by the plate from the negatively-charged carbon molecules which are projected against it from the negative leg, across the highly perfect vacuum. I have tried experiments with lamps in which the collecting plate is placed in all kinds of positions, and has various forms, some of which are here, and are represented in the diagrams before you; but the result may all be summed up by saying that the greatest effects are produced when the collecting plate is as near as possible to the base of the negative end of the loops, and, as far as possible, encloses, without touching, the carbon conductor. Time will not permit me to make more than a passing reference to the fact that the magnitude of the current flowing through the galvanometer when connected between the middle plate and the positive terminal of the lamp often "jumps" from a low to a high value, or *vice versâ*, in a remarkable manner, and that this sudden change in the current can be produced by bringing strong magnets near the outside of the bulb.

Let us now follow out into some other consequences this hypothesis that the interior of the bulb of a glow lamp when in action is populated by flying crowds of carbon atoms all carrying a negative charge of electricity. Suppose we con- [fol. 3018] nect our middle collecting plate with some external reservoir of electric energy, such as a Leyden jar, or with a condenser equivalent in capacity to many hundreds of Leyden jars, and let the side of the condenser which is charged positively be first placed in connection through a galvanometer with the middle plate (*see* Fig. 10), whilst the negative side is placed in connection with the earth. Here is a condenser of two microfarads capacity so charged and connected. Note what happens when I complete the circuit and illuminate the lamp by passing the current through its filament. The condenser is at once discharged. If, however, we repeat the same experiment with the sole difference that the negatively charged side of the condenser is in connection with the middle plate then there is no discharge. The experimental results may be regarded

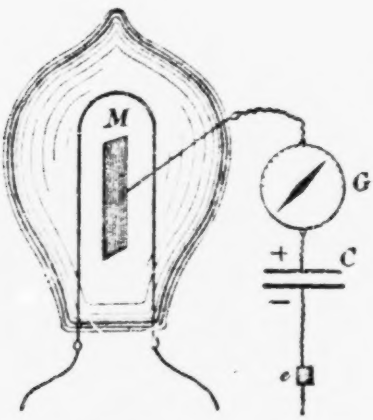

FIG. 10. Charged condenser C discharged by middle plate M, when the positively charged side of condenser is in connection with the plate and other side to earth e.

from another point of view. In order that the condenser may be discharged as in the first case it is essential that the negatively charged side of the condenser shall be in connection with some part of the circuit of the incandescent carbon loop. This experiment with the condenser discharged by the lamp may be then looked upon as an arrangement in which the plates of a charged condenser are connected respectively to an incandescent carbon loop and to a cool metal plate, both being enclosed in a highly vacuous space, and it appears that when the incandescent conductor is the negative electrode of this arrangement the discharge takes place, but not when the cooler metal plate is the negative electrode of the charged condenser. The negative charge of the condenser can be carried across the vacuous space from the hot carbon to the colder metal plate, but not in the reverse direction.

This experimental result led me to examine the condition of the vacuous space between the middle metal plate and the negative leg of the carbon loop in the case of the lamp employed in our first experiment. Let us return for a moment to that lamp. I join the galvanometer between the middle plate and the negative terminal of the lamp, and find, as before, no indication of a current. The metal plate and the negative terminal of the lamp are at the same electrical potential. In the circuit of the galvanometer we will insert a single galvanic cell having an electromotive force of rather over one volt. In the first place let that cell be so inserted that its negative pole is in connection with the middle plate, and its positive pole in connection through the galvanometer with the negative terminal of the lamp (see Fig. 11). Regarding the circuit of that cell alone, we find that it consists of the cell itself, the galvanometer wire, and that half inch of highly vacuous space between the hot carbon conductor and the middle plate. In that circuit the [fol. 3019] cell cannot send any sensible current at all, as

it is at the present moment connected up. But if we reverse the direction of the cell so that its positive pole is in connection with the middle plate, the galvanometer at once gives indications of a very sensible current. This highly vacuous space, lying between the middle metal plate on the one hand and the incandescent carbon on the other, possesses a kind of unilateral conductivity, in that it will allow the current from a single galvanic cell to pass one way but not the other. It is a very old and familiar fact, that in order to send a current from a battery through a highly rarefied gas by means of metal electrodes, the electromotive force of the battery must exceed a certain value. Here, however, we have indication that if the negative electrode by which that current seeks to enter the vacuous space is made incandescent the current will pass at a very much lower electromotive force than if the electrode is not so heated.

A little consideration of the foregoing experiments led to the conclusion that in the original experiment, as devised by Mr. Edison, if we could by any means render the middle plate very hot, we should get a current flowing through a galvanometer when it is connected between the middle plate and the negative electrode of the carbon. This experiment can be tried in the manner now to be shown. Here is a bulb (Fig. 12) having in it two carbon loops; one of these is of ordinary size and will be rendered incandescent by the current from the mains. The other loop is very small, and will be heated by a well insulated, secondary battery. This smaller incandescent loop shall be employed just as if it were a middle metal plate. It is in fact, simply an incandescent middle conductor. On repeating the typical experiment with this arrangement we find that the galvanometer indicates a current when connected between the middle loop and either the positive *or* the negative terminal of the main carbon. I have little doubt but that if we could render the platinum plate in our first-used lamp incandescent by con

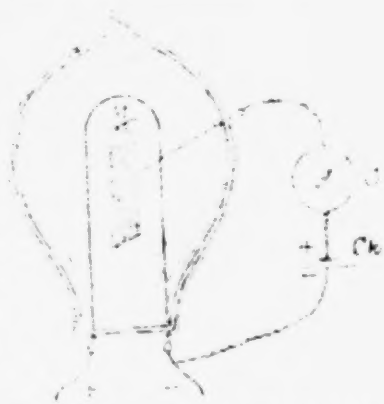

Fig. 11.—Current from Clark cell Ck being sent across the vacuous space between negative leg of carbon and middle plate M. Positive pole of cell in connection with plate M through galvanometer G.

centrating on it from outside a powerful beam of radiant heat we should get the same result.

A similar set of results can be arrived at by experiments with a *a* bulb constructed like an ordinary vacuum tube, and having small carbon loops at each end instead of the usual platinum or aluminum wires. Such a tube is now before you (*see* Fig. 13), and will not allow the current from a few cells of a secondary battery to pass through it when the carbon loops are cold. If, however, by means of well insulated secondary batteries we render both of the carbon loop electrodes highly incandescent, a single cell of a battery is sufficient to pass a very considerable current across that vacuous [fol. 3020] space provided the resistance of the rest of the circuit is not large. We may embrace the foregoing facts by saying that if the electrodes, but especially the negative electrode, which form the means of ingress and egress of a current into a vacuous space are capable of being rendered highly incandescent, and if at that high temperature they are made to differ in electrical potential by the application of a very small electromotive force, we may get under these circumstances a very sensible current through the rarefied gas. If the electrodes are cold a very much higher electromotive force will be necessary to begin the discharge or current through the space.* These facts have been made the subject of elaborate investigation by Hittorf and Goldstein, and more recently by Elster and Geitel. It is to Hittorf that I believe we are indebted for the discovery of the fact that by heating the negative electrode we greatly reduce the apparent resistance of a vacuum.

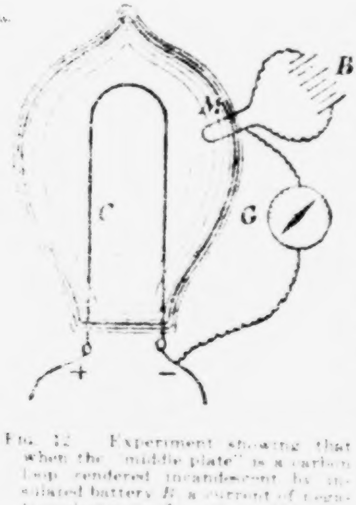

Fig. 12. Experiment showing that when the "middle plate" is a carbon loop rendered incandescent by insulated battery *B*, a current of negative electricity flows from *M* to the positive leg of main carbon *C* across the vacuum.

Permit me now to pave the way by some other experiments for a little more detailed outline of the manner in which I shall venture to suggest these negative molecular charges are bestowed. This is really the important matter to examine. In seeking for some probable explanation of the manner in which these wandering molecules of carbon in the glow-lamp bulb obtain their negative charges, I fall

back for assistance upon some facts discovered by the late Prof. Guthrie. He showed some years ago new experiments

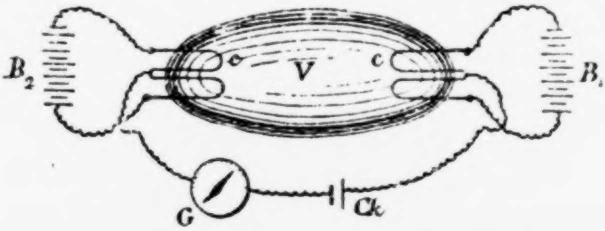

FIG. 13.—Vacuum tube having carbon loop electrodes, *cc*, at each end rendered incandescent by insulated batteries, B_1 B_2, showing current from Clark cell, *Ck*, passing through the high vacuum when the electrodes are incandescent.

on the relative powers of incandescent bodies for retaining positive and negative charges. One of the facts he brought forward[2] was that a bright red-hot iron ball, well insulated, could be charged negatively, but could not retain for an instant a positive charge. He showed this fact in a way which it is very easy to repeat as a lecture experiment. Here is a gold-leaf electroscope, to which we will impart a positive charge of electricity, and project the image of its divergent leaves on the screen. A poker the tip of which had been made [fol. 3021] brightly red hot is placed so that its incandescent end is about an inch from the knob of the electroscope. No discharge takes place. Discharging the electroscope with my finger, I give it a small charge of negative electricity, and replace the poker in the same position. The gold leaves instantly collapse. Bear in mind that the extremity of the poker when brought in contiguity to the knob of the charged electroscope becomes charged by induction with a charge of the opposite sign to that of the charge of the electroscope, and you will at once see that this experiment confirms Prof. Guthrie's statement, for the negatively-charged electroscope induces a positive charge on the incandescent iron, and this charge cannot be retained. If the induced charge on the poker is a negative charge it is retained, and hence the positively-charged electroscope is not discharged, but the negatively-charged electroscope at once loses its charge. Pass in imagination from iron balls to carbon molecules. We may ask whether it is a legitimate assumption to suppose the same fact to hold good for them, and that a hot

[2] "On a New Relation between Electricity and Heat," *Phil. Mag.*, Vol. XLV, p. 308. 1873.

carbon molecule or small carbon mass just detached from an incandescent surface behaves in the same way and has a greater grip for negative than for positive charge? If this can possibly be assumed, we can complete our hypothesis as follows: Consider a carbon molecule or small congerie of molecules just set free by the high temperature from the negative leg of the incandescent carbon horseshoe. This small carbon mass finds itself in the electrostatic field between the branches of the incandescent carbon conductor (*see* Fig. 14). It is acted upon inductively, and if it behaves like the hot iron ball in Prof. Guthrie's experiment it loses its positive charge. The molecule then being charged negatively is repelled along the lines of electric force against the positive leg. The forces moving it are electric forces, and the repetition of this action would cause a torrent of negatively-charged molecules to pour across from the negative to the positive side of the carbon horseshoe. If we place a metal plate in their path, which is in conducting connection with the positive electrode of the lamp carbon, the negatively-charged molecules will discharge themselves against it. A plate so placed may catch more or less of this stream of charged molecules which pour across between the heels of the carbon loop. There are many extraordinary facts, which as yet I have been able only imperfectly to explore, which relate to the sudden changes in the direction of the principal stream of these charged molecules, and to their guidance under the influence of magnetic forces. The above rough sketch of a theory must be taken for no more than it is worth, viz., as a working hypothesis to suggest further experiments.

Fig. 14. Rough diagram illustrating a theory of the manner in which projected carbon molecules may acquire a negative charge.

These experiments with incandescence lamps have prepared the way for me to exhibit to you some curious facts with respect to the electric arc, and which are analogous to those which we have passed in review. If a good electric [fol. 3022] arc is formed in the usual way, and if a third insulated carbon held at right angles to the other two is placed so that its tip just dips into the arc (*see* Fig. 15), we can show a similar series of experiments. It is rather more under control if we cause the arc to be projected against

the third carbon by means of a magnet. I have now formed on the screen an image of the carbon poles and the arc between them in the usual way. Placing a magnet at the back of the arc, I cause the flame of the arc to be deflected laterally and to blow against a third insulated carbon held in it. There are three insulated wires attached respectively to the positive and to the negative carbons of the arc, and to the third or insulated carbon, the end of which dips into the flame of the arc projected by the magnet. On starting the arc this third carbon is instantly brought down to the same electrical potential as the negative carbon of the arc, and if I connect this galvanometer in between the negative carbon and the third or insulated carbon I get, as you see, no indication of a current. Let me, however, change the connections and insert the circuit of my galvanometer in between the positive carbon of the arc and the middle carbon, and we find evidence, by the violent impulse given to the galvanometer that, there is a strong current flowing through it. The direction of this current is equivalent to a flow of negative electricity from the middle carbon through the galvanometer to the positive carbon of the arc. We have here then the "Edison effect" repeated with the electric arc. So strong is the current flowing in a circuit connecting the middle carbon with the positive carbon that I can, as you see, ring an electric bell and light a small incandescent lamp when these electric-current detectors are placed in connection with the positive and middle carbons.

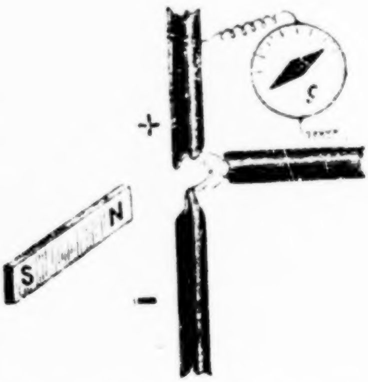

FIG. 15. Electric arc projected by magnet against a third carbon, and showing strong electric current flowing through a galvanometer, G, connected between the positive and third carbon.

We also find that the flame-like projection of the arc between the negative carbon possesses a unilateral conductivity. I join this small secondary battery of fifteen cells in series with the galvanometer, and connect the two between the middle carbon and the negative carbon of the arc. Just as in the analogous experiment with the incandescent lamp, we find we can send negative electricity along the flame of

the arc one way but not the other. The secondary battery causes the galvanometer to indicate a current flowing through it when its negative pole is in connection with the negative carbon of the arc (*see* Fig. 16), but not when its positive pole is in connection with the negative carbon. On examining the third or middle carbon after it has been employed in this way for some time we find that its extremity is cratered out and converted into graphite, just as if it had been employed as the positive carbon in forming an electric [fol. 3023] arc. Time forbids me to indulge in any but the briefest remarks on these experiments; but one suggestion may be made, and that is that they seem to indicate that the chief movement of carbon molecules in the electric arc is *from* the negative *to* the positive carbon. The idea suggests itself that, after all, the cratering out of the positive carbon of the arc may be due to a sand-blast action of this torrent of negatively-charged molecules, which are projected from the negative carbon. If we employ a soft iron rod as our lateral pole, we find that, after enduring for some time the projection of the arc against it, it is converted at the extremity into *steel*.

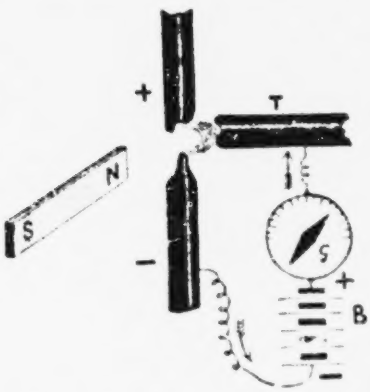

FIG. 16. Galvanometer *G* and battery *B* inserted in series between negative carbon of electric arc and a third carbon to show unilateral conductivity of the arc between the negative and third carbons.

Into the fuller discussion as to the molecular actions going on in the arc, the source and nature of that which has been called the counter-electromotive force of the arc, and the causes contributing to produce unsteadiness and hissing in the arc, I fear that I shall not be able to enter, but will content myself with the exhibition of one last experiment, which will show you that a high vacuum or, indeed, any vacuum, is not necessary for the production of the "Edison effect." Here is a carbon-horseshoe-shaped conductor, not enclosed in any receiver (see Fig. 17). Close to the negative leg or branch, yet not touching it, we have adjusted a little metal plate. The sensitive galvanometer is connected between this metal plate and the

base of the other or positive leg of this carbon arch. On sending a current through the carbon sufficient to bring it to bright incandescence, the galvanometer gives indications of a current flowing through it, and as long as the carbon endures, which is not, however, for many seconds, there is a current of electricity through it equivalent to a flow of negativ electricity from the plate through the galvanometer to the positive electrode of the carbon. The interposition of a thin sheet of mica between the metal plate and the negative leg of the carbon loop entirely destroys the galvanometer current.[3]

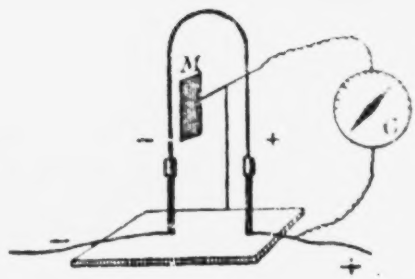

FIG. 17.—"Edison effect" Experiment shown with carbon in open air.

These experiments and brief expositions cover a very small portion of the ground which is properly included within the limits of my subject. Such fragments of it as we have been able to explore to-night will have made it clear [fol. 3024] that it is a region abounding in interesting facts and problems in molecular physics. The glow lamp and the electric arc have revolutionised our methods of artificial lighting, but they present themselves also as subjects of scientific study, by no means yet exhausted of all that they have to teach.

[fol. 3025-3026] DEFENDANT'S EXHIBIT M-1

Transactions of American Institute of Electrical Engineers, 1897

The second part of this paper, which relates to the conductivity of the vacuous space surrounding incandescent filaments, may be considered as a discussion of the paper upon the "Edison Effect" in incandescent lamps, which was read before the INSTITUTE by Professor Houston, in October, 1884, and which was the first paper read before this society.

[3] This last experiment is due to my assistant, Mr. A. H. Bate.

"Edison Effect" is the name given to the effect produced by those currents, first observed by Mr. Edison, which pass from one leg of an incandescent filament across the vacuous space to the other leg, and which can be observed by connecting a galvanometer between the positive lamp terminal and a wire sealed into the bulb and projecting into the vacuous space.

Fig. 4

Figure 4, which is taken from Professor Houston's paper, serves to illustrate Mr. Edison's original experiment. The galvanometer indicates a current flowing from the positive lamp terminal through the galvanometer and third lamp wire, and through the vacuous space to the negative leg of the incandescent filament. If the external connection of the galvanometer be changed from the positive terminal to the negative terminal, no current will flow through the galvanometer. This effect can be observed in the mos, highly exhausted lamps. A lamp so highly exhausted that it shows no glow when tested with an induction coil, giving a spark $^3/_4$" long, will allow a current sufficiently large to show plainly on a not very sensitive galvanometer, to pass through its vacuous space. This current increases as the temperature of the filament is increased, but in a well exhausted lamp is never greater than a very few milliamperes, when the lamp is burned at about $2^1/_2$ watts per candle.

In 1884 Mr. Preece secured from Mr. Edison some lamps having wires sealed into the bulbs, and read a paper before the Royal Society describing some experiments made upon them, illustrating the "Edison Effect."

Professor Fleming read a most elaborate paper before the Physical Society of London, in March, 1896, upon this same subject. Professor Fleming's experiments proved that in well exhausted lamps the vacuum is not a conductor in the ordinary sense of the word, and that the current which passes through it is carried by negatively charged [fol. 3027] molecules, which pass constantly from the negative leg of the incandescent filament to the positive leg and to any inserted wire, thus bringing the inserted wire to the same potential as the negative leg. Professor Fleming also proved that these molecules pass in straight lines, and that their passage is completely or almost completely stopped by a glass or mica screen placed between the negative leg and

the inserted wire. The following experiments serve to illustrate these effects:

Figure 5 shows a lamp having a glass tube surrounding one leg of the filament, and a wire sealed in the side of the bulb, which projects into the centre of the vacuous space. When the leg of the filament which is in the glass tube is made positive, and the filament heated to about a $2\frac{1}{2}$ watts-per-candle temperature, the galvanometer, which is connected between the wire and the positive lamp terminal, shows a strong deflection, but when the leg in the tube is

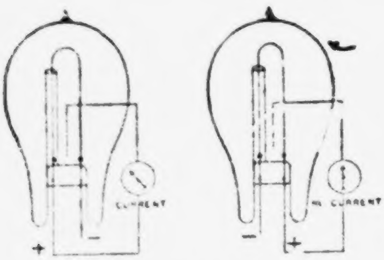

FIG. 5.

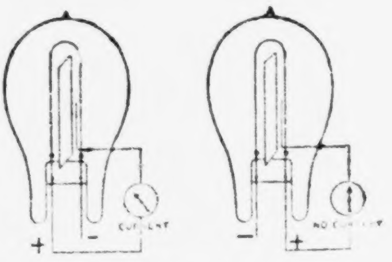

FIG. 6.

made negative, the galvanometer, being as before connected between the wire and the positive lamp terminal, shows no deflection.

Figure 6 shows a lamp having a platinum plate $2\frac{1}{4}$" long and $\frac{3}{4}$" wide between the legs of the filaments, and a wire inserted in the vacuous space. I also used lamps having a similar plate made of glass, similarly placed. In both of these lamps, when the vacuum was high, no current was produced between the wire and the positive terminal when the wire was shielded from the negative leg; but shielding the wire from the positive leg made no hindrance to the passage of the current. The facts that no current flows when the galvanometer is connected between the negative terminal of the lamp and the inserted wire, and that a shield between the positive leg and the inserted wire has no effect upon the current, show that positively charged molecules are not emitted by the positive leg; while the screen effects just described show that the negatively charged molecules pass in straight lines.

The facts, then are these: The galvanometer indicates a current flowing, as we designate the direction of currents, from the wire to the negative leg; while experiments prove that the charged molecules which carry the current actually pass from the negative leg to the wire. These facts

are entirely in accord with the results obtained by Crookes and others in their investigations of currents in high vacua. [fol. 3028] If an alternating current is used to render the filament incandescent, the galvanometer will indicate a current with the connection made to either lamp terminal, because both are equally positive. The current thus produced is a uni-directional one in the galvanometer, and illustrates very well the uni-lateral conductivity between the incandescent filament and the wire.

Mr. Preece states in his paper that lamps which show a blue glow in the vacuous space give stronger "Edison Effects" than those which do not show it. Professor Fleming also observes that poorly exhausted lamps give slightly greater effects, but neither of them paid much attention to these lamps.

The blue glow in lamps has long been associated in my mind with a condition of the vacuum which makes it a conductor. Lamps in the process of exhaustion, just before the vacuum is perfected, show this blue very plainly, if a little more than normal current is sent through the filament. The blue increases as the current is increased and becomes very dense at very high temperatures. This blue indicates a current passing from one leg of the filament across the vacuous space to the other leg.

I observed several years ago, that at a high temperature .04 or .05 of an ampere more current flowed through a lamp showing a good blue than through the same lamp, at the same voltage, when the blue had disappeared. I concluded that this extra current flowed through the vacuous space between the legs of the filament.

If a direct current about 20 or 30 per cent. greater than the normal current be passed through a lamp filament when the vacuous space shows a blue glow, the positive joint between the filament and the platinum wire gets red hot, while the negative joint remains cool.

I have always considered this as proof that the resistance to the passage of a current through a vacuous space was chiefly at the surface of the positive electrode, as the energy was chieflly developed there. If an alternating current is used, both joints get equally hot.

If a lamp be burned at normal incandescence with a direct current, when the vacuous space shows a good deal of this blue, the negative leg of the filament becomes coated with a carbon soot. This effect can be obtained in a few minutes

if the blue is dense and the filament is run above a normal incandescence. This I have considered to be due to an electrolysis of a hydrocarbon gas in the lamp.

The lamps which show only a slight amount of this blue glow, if burned at normal incandescence, will not show this carbon soot perceptibly, and the blue will entirely disappear if the lamp is burned for a few hours. This blue is caused more by the character of the residual gas than by the degree of exhaustion. Lamps having a residual of bromine vapor do not show it at all, neither do they show any "Edison Effect." I have seen ordinary lamps ready to be sealed off the pumps which showed blue and then no blue, and blue again, at regular intervals of a few seconds. Such lamps show corresponding changes in the "Edison Effect."

[fol. 3029] If the current be gradually increased in a lamp which shows good blue, the positive joint will get hotter and hotter and finally its platinum wire will fuse. At this stage the resistance to the flow of current across the vacuous space is not great, and if the conditions are such that at this time all the resistance in circuit with the lamp has been cut out, so that the current flowing will be practically determined by the resistance of the lamp and the leads, enough current will flow through the vacuous space to

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showing about as strong effects as 140-volt lamps. The energy they exhibit in one direction seems to be very much

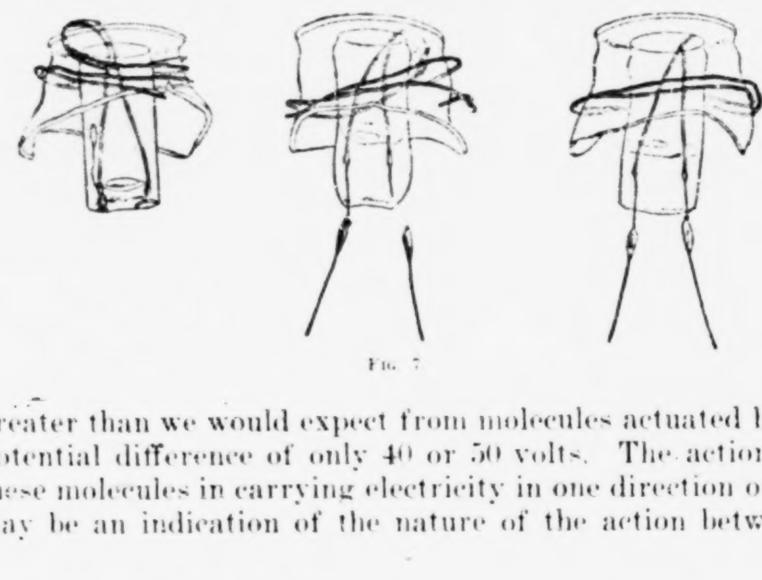

Fig. 7

greater than we would expect from molecules actuated by a potential difference of only 40 or 50 volts. The action of these molecules in carrying electricity in one direction only, may be an indication of the nature of the action between

molecules in solid conductors carrying currents, rather than an illustration of the action of statically charged molecules.

Discussion

Mr. John W. Howell: After I had written this paper, I broke the lamp having the graphite filament and took the filament out—a part of it—and measured its specific resistance. Its specific resistance (the resistance of a piece 1 inch long and 1 circular mil area) was 450 ohms. The lowest specific resistance I have ever measured of amorphous carbon is about 2200 ohms. The treatment obtained by hydrocarbon deposit is about 350 ohms, which is about six or seven times as low; and this graphite lamp was 450 ohms, which was very nearly the figure of the carbon obtained by treatment, and I think if it had been a more solid graphite it would have been lower. I can also say that the specific gravity of graphite is practically the same as the specific gravity of the carbon obtained by hydrocarbon deposit.

The President: How was that filament made?

Mr. Howell: It was simply made by making a die, filling it with graphite and solidifying it under great pressure—so great pressure that it made a solid graphite filament of it. [fol. 3030] Dr. A. E. Kennelly: I believe that I voice the general sentiment in saying that this is a very interesting paper, both by reason of what it contains of investigation and by reason of what it suggests for further inquiry.

I remember having taken part in the measurements of resistance in the lamp filament referred to. I believe that the theory given in this paper was suggested at that time for the apparently abnormal behavior of its resistances, but the additional evidence was not then forthcoming which enables Mr. Howell to make so strong a case for that theory in this paper.

It is perhaps no more surprising that graphite should differ markedly from ordinary carbon in its temperature co-efficient of resistivity, than that diamond should differ markedly from ordinary carbon in its hardness.

Incidentally it is curious to observe from the curves in the paper that approximately five per cent. of the voltage needed to produce an inefficiency of three watts per candle, raised the temperature of the filaments experimented on to 500° F., or 260° C.

It has long been known that the passage of a continuous current through a Geissler tube set up a series of pulsatory currents or discharges, which are capable of producing alternating currents in a separate circuit, through the intermediary of an alternating current transformer. So far as I know, however, it has been pointed out for the first time in this paper, that an alternating current passed through an incandescent lamp giving the "Edison Effect" is capable of producing in a branch circuit through a third wire in a lamp, continuous or at least undirectional currents. Consequently it is interesting to observe that a vacuum tube, in the broadest sense of the term, is capable of supplying not only alternating currents from continuous currents, but also continuous currents from alternating currents.

As regards the results obtained in the interesting manner described, it would appear that some of these observations differ from those quoted as obtained by Dr. Fleming. It would seem that Dr. Fleming took the position that the blue discharge can only travel in straight lines, whereas in some of the experiments here referred to, as, for example, those in connection with Figs. 11 and 12, the blue discharge and the "Edison Effect" did apparently go around a corner, and a sharp corner too.

I am unable to follow the conclusion mentioned by Mr. Howell, that the change in the development of heat from the positive joint to the middle wire, when the connections are changed, indicates that no bombardment can take place. It seems to me possible that bombardment might still take place under a directive influence determined by the point of connection. No doubt Mr. Howell can make this matter clear.

Mr. E. A. Colby: I am deeply interested in Mr. Howell's paper, especially the latter part of it, referring to the so called "Edison Effect." While I am not prepared to-night [fols. 3031-3032] to present any theory as to the phenomena observed, I can say that the characteristics which Mr. Howell has mentioned are well known to me. I would like to ask if he has substituted for the galvanometer which he used in measuring the currents, the still more sensitive instrument, the telephone, and whether he has attempted with its aid to explore the vacuous space by the insertion of platinum

wires at different points in the glass bulb. Some years ago I tried an experiment of this character which was described in a discussion before the INSTITUTE. I sealed into a lamp bulb in the plane of the filament a number of platinum wires about one inch apart. Connecting the terminals of the telephone with the positive leg of the lamp, and with one of these wires I observed a note in the telephone which varied in pitch according to the position of the wire sealed into the bulb. When the telephone was connected to the positive leg on one side, and to the platinum terminal which was nearly at the middle of the filament, or more correctly on the diagonal to positive terminal of the area enclosed by the legs of the filament, I obtained the maximum note, and as I carried this terminal of the telephone near to the negative leg of the filament I got practically no sound whatever. I also inserted in a similar

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[fol. 3033] DEFENDANT'S EXHIBIT N-1

Proceedings of Physical Society of London, March 27, 1896

XVII. A Further Examination of the Edison Effect in Glow Lamps. By J. A. Fleming, M.A., D.Sc. F.R.S., Professor of Electrical Engineering in University College, London [1]

1. The experiments described in this paper had for their object the further examination of an effect which can be produced in certain forms of electric incandescence lamps and to which attention was first drawn by Mr. Edison in 1884. This effect may be generally described as follows: A carbon filament incandescence lamp having the ordinary horse shoe loop carbon has a metallic plate placed in the exhausted bulb, the plate being carried on a platinum wire sealed through the globe, and fixed so as to stand up between the legs of the horse shoe (see fig. 1). If the lamp is set in action at the usual incandescence by a continuous current of the proper strength, and a suitable sensitive galva-

[1] Read March 27, 1896

nometer is connected between the insulated metal plate and the *positive* terminal of the lamp, it will in general be found to indicate a current of some milliamperes flowing through it. The direction of this current is *from* the positive electrode of the lamp through the galvanometer *to* the insulated metal plate, or wire. When the same galvanometer is connected between the *negative* pole of the lamp and the middle plate, unless it is very sensitive, it indicates no current. This effect was very carefully examined by Mr. W. H. Preece in 1885, and he subjected it to a systematic examination by the aid of a number of lamps having such metal plates [fol. 3034] placed in various positions.[2] By this observer a number of very interesting facts were collected, the result of which was to point out the general nature of the phenomenon. A sufficient number of new questions were, however, suggested by the information so acquired to invite further inquiry. Whilst confirming and re-examining the experimental results obtained by Mr. Preece, some facts that

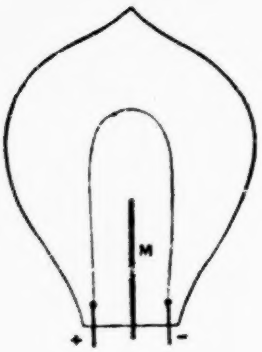


FIG. 1.

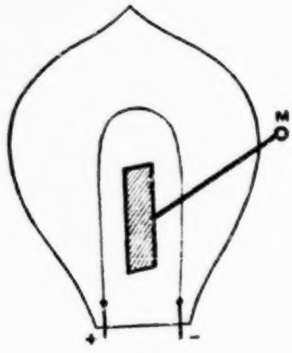


FIG 2.

had previously escaped notice presented themselves, which it is the object of this paper to describe.

§ 2. The first experiments were made with a lamp of the form shown in fig. 2, similar to some used by Mr. Preece in his experiments. A metal plate, generally of aluminum, is

[2] "On a Peculiar Behaviour of Glow-Lamps when raised to High Incandescence," by W. H. Preece, F.R.S. Proceedings of the Royal Society, 1885, p. 219.

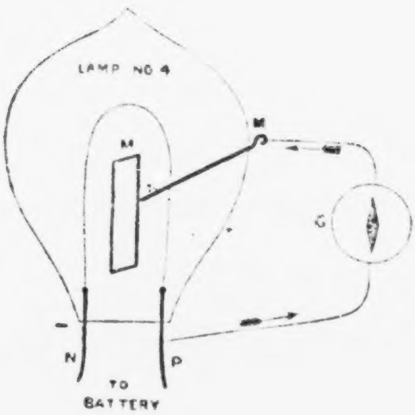


Fig. 3

supported on a platinum wire sealed through the bulb or glass receiver, the plate being so fixed that its plane is at right angles to the plane of the loop of the carbon, and as nearly as possible midway between the legs. The plate therefore projects between the legs of the horse-shoe carbon, and the carbon conductor arches over it without touching it. The plate is entirely insulated from the carbon.

The preliminary experiments with this normal type of middle-plate lamp consisted in determining the effective potential difference between the third terminal and one or other of the two electrodes of the carbon filament when the lamp was subjected to varying steady electromotive forces sufficient to raise the temperature of the carbon from dull red to vivid incandescence, and in determining the magnitude of the current flowing in a circuit connecting the middle plate with one or other of the electrodes of the lamp.

3. *Experiment 1.*—An ordinary carbon filament electric lamp, having the horse-shoe shaped conductor, had a plati- [fol. 3635] num plate (see fig. 3) about 2.5 centimetres long by 1.5 centimetres wide welded to a platinum wire, sealed through the side of the bulb. The plate was so placed as to project between the legs of the carbon conductor, having its plane at right angles to the plane of the horse-shoe, and initially fixed about halfway between the two legs. This lamp will be described in the subsequent paragraphs as Lamp No. 4. Under a steady electromotive force of 40 volts, this lamp took 3. amperes when working at the normal temperature corresponding to about 3.5 watts per candle-power. When a milamperemeter having a resistance of 6372 ohms was joined between the base P of the *positive* leg of the carbon (see fig. 4) and the middle plate M, a current was found passing through the galvanometer from the terminal P to the plate M. This current had a magnitude of

about 3 milliamperes when the carbon was in the normal state of incandescence.

If the milamperemeter was connected between the negative electrode of the lamp and the middle plate, no current perceptible by this galvanometer was found. On replacing the milamperemeter by a more sensitive Elliott mirror galvanometer (resistance 7142 ohms) it was found that a small

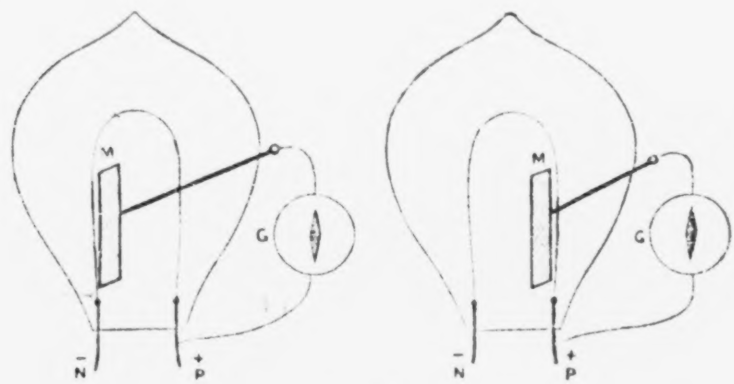


Fig. 4.

current passed through it, when joined in between the negative electrode of the lamp and the middle plate, but that this current had a magnitude hardly exceeding .0001 of a milliampere when the lamp was at its normal incandescence.

In order to avoid repetition, it may be here said that, unless otherwise stated, the terminal of the lamp in connexion with the positive pole of the working battery will be spoken of as the positive electrode of the lamp; that in connexion with the negative pole of the battery as the negative electrode. For brevity's sake, the half of the carbon filament between the centre of the filament and the positive electrode will be called the *positive leg*, and the other half the *negative leg*.

4. A preliminary series of experiments was made with lamp No. 4 by placing the lamp in a photometer and deter- [fol. 3536] mining the watts per candle-power and the current taken by the lamp corresponding to various working electromotive forces, taken over the whole range of electromotive force from that necessary just to render the filament incandescent to the highest the lamp could with safety endure. In any subsequent experiments, the simple measurement of the potential-difference between the electrodes of

the lamp enabled the rate of dissipation of energy in the filament and the watts per candle power to be deduced. It may here be remarked that in the preliminary experiments some difficulties arose from the occlusion of residual gas by the middle metal plate, but finally this was overcome, and the vacuum in these experimental bulbs made and preserved as perfect as in good ordinary commercial lamps. The following results were then obtained with this lamp No. 4. The lamp was raised to various degrees of incandescence by varying the working volts by the aid of a rheostat in series with the lamp.

The milamperemeter was employed to measure the effective potential-difference between the positive electrode of the lamp and the middle plate and then, tabulating against the working volts of the lamp the current in milliamperes flowing through the galvanometer, the potential-difference between the middle plate and the positive electrode of the lamp was calculated from these figures. The results are given in the table below (Table No. 1).

TABLE No. 1. *Lamp No. 4, milamperemeter*

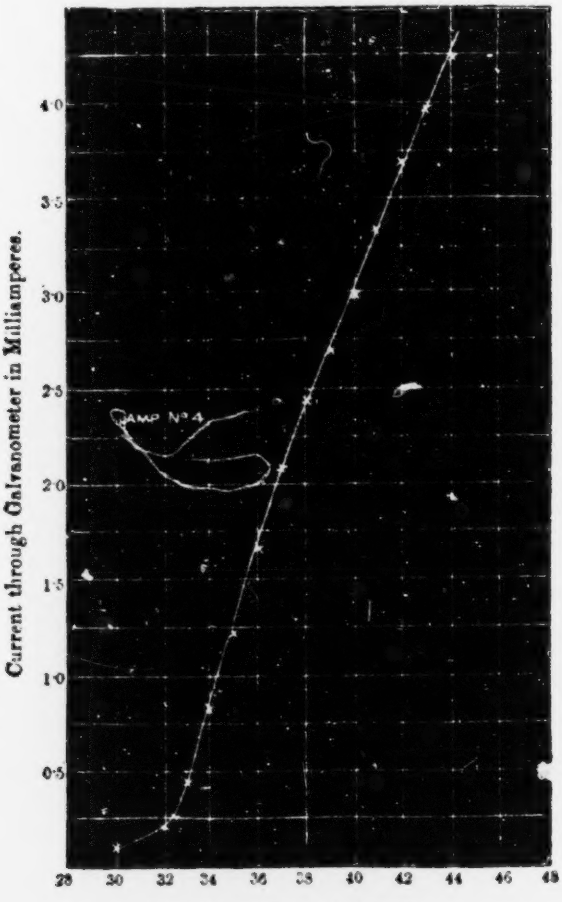
Table showing the volts between the middle plate and the positive electrode, and the current flowing through a galvanometer of 6372 ohms resistance connecting them, taken for various working voltages of the lamp.

Working volts of lamp	Volts between plate and positive lamp electrode	Current in milliamperes through galvanometer	Working volts of lamp	Volts between plate and positive lamp electrode	Current in milliamperes through galvanometer
30	.54	.085	36	10.7	1.69
32	1.2	.190	37	12.7	2.01
32.5	1.6	.25	38	14.9	2.36
33	2.8	.44	39	17.1	2.71
33.5	4.7	.74	40	18.9	2.99
34	5.3	.84	41	21.4	3.37
34.5	7.1	1.12	42	23.4	3.71
35	7.8	1.23	43	25.2	3.99
			44	26.8	4.25

The results given in table No. 1 are plotted in curve No. 1, in which horizontal abscissae represent to scale the working volts of the lamp and vertical ordinates the milliampere currents through the galvanometer. It will be seen that the curve representing the current from lamp electrode to plate takes a rather sharp turn upwards at a point corresponding to 35 working volts, and this occurs when the

lamp is working at about 7.8 watts per candle-power. Beyond this point the curve is very approximately a straight line. Accordingly, at and beyond the volts at which the carbon filament becomes fairly well incandescent, [fol. 3037] the effective potential-difference between the

TABLE No. 1.—*Curve No. 1*



Working Volts of Lamp.

middle plate and the positive lamp electrode is very nearly a linear function of the lamp voltage; and at the normal working volts, viz. 40 volts, this potential-difference between the middle plate and the positive electrode so determined is apparently about half that between the lamp terminals, the plate being nearly midway between the carbon legs. The results given in Table 1 are the mean of several observations, but it was noticed that when the lamp was main-

tained at a steady voltage, the potential-difference between the middle plate and the positive electrode would often *jump suddenly* from one value to another. This effect renders it difficult to obtain the stable values of the plate and positive electrode potential-difference. Corresponding to any definite steady voltage on this lamp, the current may have one or other of two values, but not always permanently preserving either; a galvanometer deflection indicating say [fol. 3038] 10 volts between the plate and positive electrode of the lamp will often slowly increase until after a few minutes it is 12 or 14 volts, yet all the time the working volts on the lamp are remaining perfectly constant. It will then often suddenly jump perhaps to 22 volts, and then slowly decrease to 19 volts, or so. This tendency of the potential-difference betwen the middle plate and positive lamp electrode to jump from a low to a high value, or *vice versâ*, is most marked in lamps in which the plate is about half-way, and symmetrically placed, between the legs of the carbon. We shall speak of these two values as the high and low value of the current through the galvanometer, and defer until later a discussion of some other causes tending to make the current pass from a high to a low value or the reverse, as well as its possible explanation. In Table No. 2 are tabulated a set of observations on the same lamp No. 4, showing these double values which the potential-difference and current may have, and it may be here noted that in the previous Table No. 1, the higher values have been taken in those cases in which double values exist.

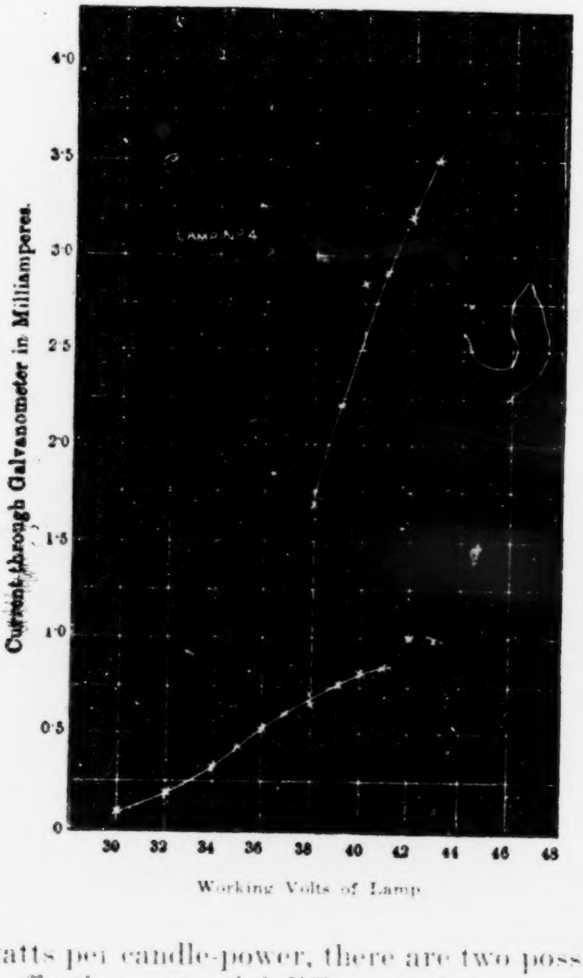
TABLE No. 2.—*Lamp No. 4, milamperemeter.*

Table showing the multiple values of the potential-difference between the middle plate and positive electrode of the lamp corresponding to various given working voltages.

Working volts of the lamp	Volts between the middle plate and positive electrode of the lamp	Current through the graded galvanometer in milliamperes	Working volts of the lamp	Volts between the middle plate and positive electrode of the lamp	Current through the graded galvanometer in milliamperes
30	.6	.095	39	4.3	.761
32	1.1	.174	"	14.0	2.22
34	2.0	.317	40	5.1	.809
35	2.6	.412	"	18.1	2.87
36	3.2	.507	41	5.3	.841
37	3.9	.618	"	18.4	2.91
38	4.3	.682	42	6.4	1.01
"	4.5	.714	"	20.0	3.17
"	11.0	1.74	43	6.2	.983
			"	22.0	3.49

These observations are plotted in Curve No. 2, in which the abscissæ represent the working volts of the lamp and the ordinates the current in milliamperes flowing through the galvanometer connecting the positive electrode and the middle plate. It is seen that corresponding to any working pressure above 38 volts for this lamp, which is equivalent

TABLE No. 2.—*Curve No. 2*



to 4.2 watts per candle-power, there are two possible values of the effective potential-difference between the middle plate and the positive electrode. As the working voltage of the lamp is gradually raised, the reading of the galvanometer inserted between the middle plate and positive electrode is also increased, but there is a great tendency to jump from a certain low value to a higher one, and this occurs

when the working pressure of the lamp is preserved steady. There is also an effect produced by the presence of a magnet near the lamp bulb. When the current is at the low value corresponding to any working voltage, the galvanometer reading does not seem to be perceptibly altered by bringing [fol. 3039] a magnet near the lamp, but when it is at its high value, the reading is sometimes increased for a little, showing a steady deflexion, and then immediately falls to its low value.

5. *Experiment 2.*—The difference of potential between the middle plate and the positive electrode of the lamp depends to a considerable extent upon the position of the middle plate. Supposing the plate to be placed with its plane perpendicular to the plane of the carbon horse-shoe and then moved to various positions between the two legs of the carbon, it is found that the difference of potential between the plate and the positive electrode will have different values according to the position of the plate. This fact was elucidated by means of the same lamp No. 4 as used above. By carefully tapping the lamp, the supporting platinum wire carrying the platinum middle plate could be bent so as to displace the plate from its symmetrical position as regards the two carbon legs, and bring it nearer to one or other of the legs. In several different positions the current flowing through the milamperemeter, when connected between the middle plate and positive electrode, was [fol. 3040] measured, the lamp being kept meanwhile at the same working electromotive force.

Estimating as nearly as possible the fractional distances, the plate was placed at distances from the negative leg equal to $^1/_{10}$, $^1/_4$, $^1/_2$, $^3/_4$, and $^9/_{10}$ of the whole distance between the positive and negative legs, and the lamp being taken through a definite cycle of volts, the potential-difference between the middle plate and the positive electrode was measured with the milamperemeter. The results are collected in the following tables. The diagrams in fig. 6 represent the horse-shoe carbon loop and the middle plate M in various positions, the galvanometer G being inserted between the plate M and the positive electrode P. By the phrase "whole distance" in the following tables is meant the whole distance or width of the space between the positive and negative carbon leg.

TABLE No. 3.—*Lamp No. 4, milampremeter*

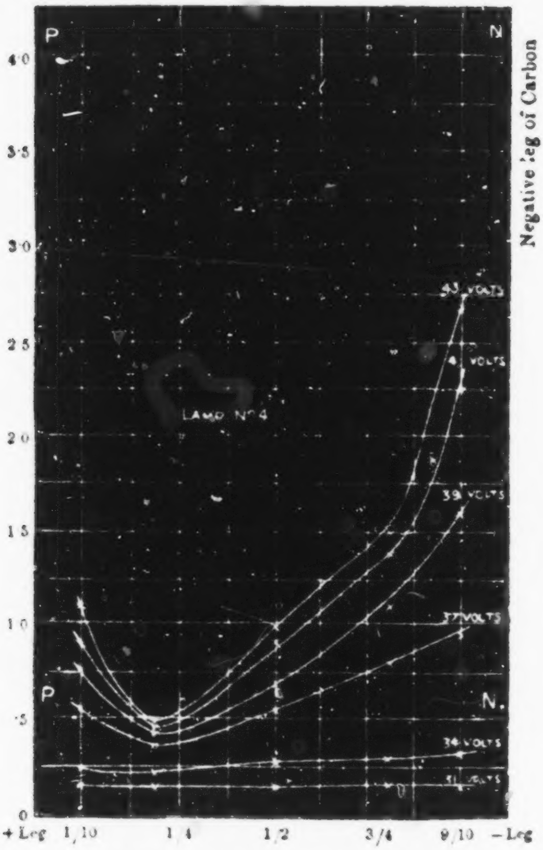
Table showing the potential-difference between the middle plate and positive electrode of the lamp at various positions of the plate and at various working voltages.

Working volts of the lamp	Volts between the middle plate and positive electrode	Current through the galvanometer in milliamperes
Middle plate at 1/10 of whole distance from negative leg		
31	9	142
34	2 2	317
37	6 0	952
39	10 2	1 61
41	14 2	2 24
43	16 8	2 66
Middle plate at ¼ of whole distance from negative leg		
31	9	142
34	1 8	285
37	5 1	809
39	7 0	1 11
41	8 7	1 38
43	9 5	1 50
Middle plate ½ of whole distance from negative leg		
31	9	142
34	1 7	269
37	3 5	555
39	4 3	682
41	5 6	888
43	6 2	983
Middle plate at ¾ of whole distance from negative leg		
31	9	142
34	1 4	222
37	2 2	349
39	2 5	396
41	2 9	460
43	3 0	476
Middle plate 9/10 of whole distance from negative leg		
31	9	142
34	1 5	238
37	3 4	539
39	4 8	761
41	5 7	904
43	6 8	1 07

[fol. 3041] The results of this Table No. 3 are plotted in the curves No. 3. These curves are to be interpreted as follows:—The two vertical lines P and N represent the two legs of the carbon horse-shoe. At various distances on the way from P to N the milliampere current through a galvanometer connected between the middle plate, placed at that point, and the positive electrode of the lamp is represented by the magnitude of the vertical ordinate of each curve. For every one of the different voltages at which the lamp is worked, there is therefore a curve representing by its ordinates this current strength through a galvanometer inserted between the middle plate, placed at these positions, and the positive electrode of the lamp, and it is seen that there is a *minimum value* for this current at a position

Table No. 3—*Curve No. 3*

The middle plate was moved along into different positions between the two carbon legs indicated by the horizontal distances, and at each position the current between the middle plate and positive electrode of the lamp is represented by the vertical ordinate of a curve. The several curves correspond to different working volts on the lamp.



Position of Plate between legs

equal to $\frac{3}{4}$ of the whole distance between the legs reckoned from the negative leg.

[fol. 3042] Imagine the middle plate therefore connected through a galvanometer with the positive electrode of the lamp, and let the middle plate be first placed close to the positive leg and then moved continuously nearer towards the negative leg. The current through the galvanometer would first fall off as the plate receded from the positive leg, and after reaching a minimum at a point about $\frac{1}{4}$ of the whole distance between the legs reckoned from the positive leg, would rise up to a maximum when the middle plate was as nearly in contact with the negative leg as possible without actually touching it.

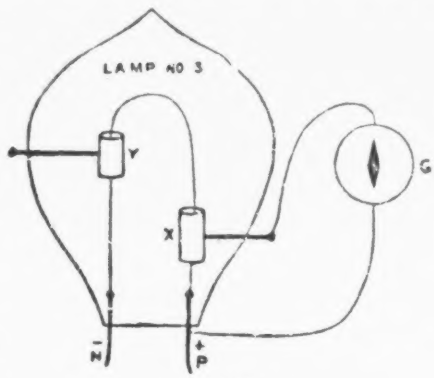


Fig. 5.

§ 6. *Experiment 3.* In order to explore more thoroughly the action of the different portions of the incandescence carbon conductor in producing this effect, a lamp was taken having a horse-shoe shaped carbon, and a pair of small platinum cylinders, held on platinum wires sealed through the glass, so placed as to embrace without touching the carbon conductor. One of these cylinders, X, was placed so as to embrace the carbon near the bottom of the leg, and the other, Y, near the spring of the arch (see fig. 5). These small cylinders had a length of about 12 millims. and a diameter of about 8 millims. so that the distance from the

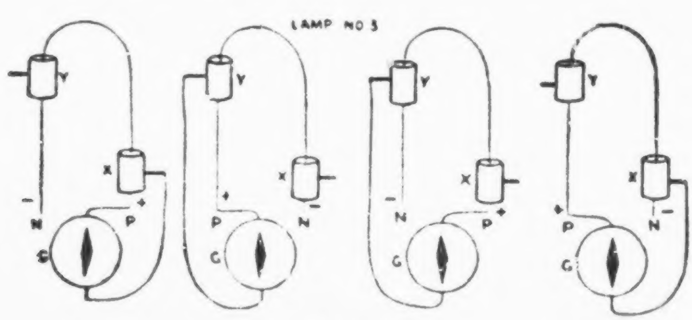
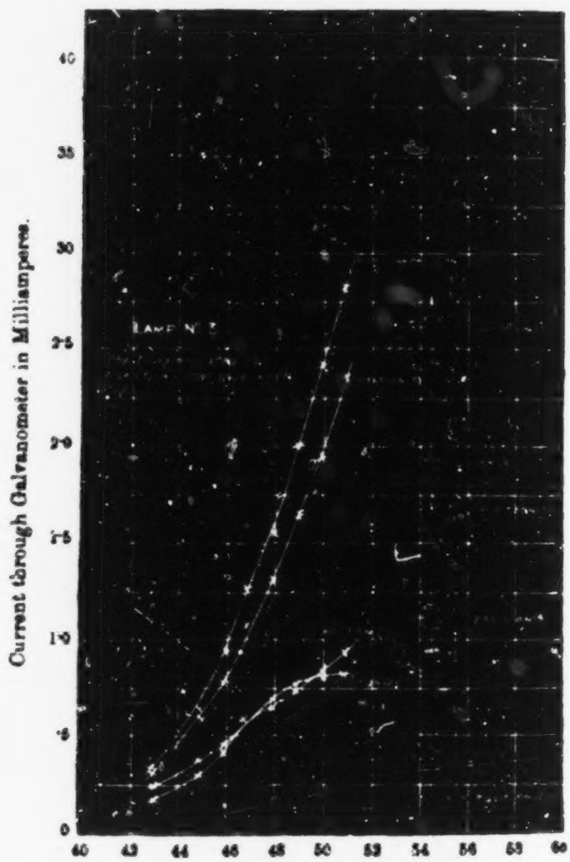


Fig. 6

Position (1) Position (2) Position (3) Position (4)

carbon filament to the inner surface of the cylinder was about 3 or 4 millims. The lamp had a rather thick carbon, and at an electromotive force of 48 volts took a current of 1.32 amperes to raise it to its normal incandescence of 18.8 candles, corresponding to 3.3 watts per candle-power. This lamp will be alluded to as Lamp No. 3.

TABLE No. 4.—*Curve No. 4*



Working Volts of Lamp

It is obvious that there are four possible arrangements in which a current can be obtained between an embracing [fol. 3043] cylinder and a positive electrode of the lamp. These are illustrated in fig. 6, in which the horse-shoe shaped line stands for the carbon filament, X and Y are the platinum cylinders, P and N are the positive and negative electrodes of the lamp, and G is the galvanometer.

We will call these arrangements (1), (2), (3), (4), as

figured. It will be seen that if we imagine the carbon filament straightened out, these four arrangements are equivalent to being able to slide a cylinder along the filament into four positions, and in each position measuring the potential-difference between the cylinder and the positive end of the carbon. We are thus able to place an embracing collecting-plate at four different places along the carbon conductor, and determine the potential difference between this embracing cylinder and the positive electrode of the lamp. A series of experiments was made with lamp No. 3, in which the working volts of the lamp were raised to various values, and in each case the potential-difference between one of the cylinders X or Y and the positive electrode of the lamp was observed as before by means of the milamperemeter. The results are given in Table 4.

TABLE NO. 4.—*Lamp No. 3, milamperemeter*

Table showing the potential-difference between a platinum cylinder embracing the carbon and the positive electrode of the lamp, and the current flowing through the galvanometer in milliamperes; for the four positions shown in fig. 6.

Working volts of the lamp	Volts between cylinder and positive electrode	Current in milliamperes through the galvanometer	Working volts of the lamp	Volts between cylinder and positive electode	Current in milliamperes through the galvanometer
	Position (1)			Position (2)	
43	1 6	25	43	1 2	19
45	2 4	38	45	2 0	31
46	2 9	46	46	2 9	36
47	3 7	58	47	3 7	58
48	4 2	67	48	4 2	67
49	4 7	74	49	4 9	78
50	5 2	82	50	5 1	81
51	5 9	93	51	5 3	84
	Position (3)			Position (4)	
43	2 1	33	43	2 2	35
45	3 9	62	45	4 0	63
46	4 9	78	46	5 9	94
47	6 8	1 08	47	8 0	1 26
48	8 2	1 30	48	9 8	1 55
49	10 4	1 65	49	12 6	1 99
50	12 3	1 95	50	15 1	2 38
51	14 9	2 36	51	18 0	2 85

These observations are plotted in Curve No. 4.

[fol. 3044] This table of observations shows us that taking the lamp at any definite voltage, the potential-difference be-

tween the positive electrode and a cylinder embracing the carbon filaments is greatest when that cylinder is as low down near the foot of the negative leg of the carbon as possible. If the cylinder is placed near the top of the negative leg that potential difference becomes less. If the cylinder is taken near the top of the positive leg or near the base of the positive leg it is least, and it seems to be a minimum when the cylinder surrounds the top of the positive leg, and is as far as possible away from the foot of the negative leg. We have here a confirmation of the fact observed with respect to lamp No. 4, viz.: that the potential difference between the positive lamp electrode and the metal plate held somewhere near the incandescent carbon conductor is greatest when the plate is as near as possible to the foot of the negative leg or negative electrode.

In this lamp No. 3, in which in all positions the cylinder employed is placed very near some point on the incandescing [fol. 2045] conductor, the current through the galvanometer joining the positive electrode and the cylinder has never been observed to jump or to take double values as in the case of lamp No. 4.

If a sensitive galvanometer is connected to the two insulated cylinders X and Y, and if in addition there is a battery in series with this galvanometer, then no current can be detected in such an arrangement even when the battery has an electromotive force of 120 volts, whether the lamp carbon is incandescent or not. Just as in the case of lamp No. 4, the current obtained by connecting either cylinder with the negative electrode of the lamp is excessively small.

In order to obtain curves showing the mode of variation of the effective difference of potential between one or other of the metal cylinders X and Y and the positive electrode of the lamp, a set of observations was made on the lamp when submitted to various working voltages, and at the same time the milamperemeter was connected first between the positive electrode and cylinder X and then between the positive electrode and cylinder Y, with the following tabulated results (p. 2044).

These results, when plotted out in curves in which horizontal ordinates represent the working volts of the lamp and the vertical ones the milliampere currents going through the galvanometer, in both cases have the same general form as curve No. 1 plotted for the case of lamp No. 4.

TABLE No. 5.—*Lamp No. 3, milamperemeter*

Table showing the potential-differences between the positive electrode of the lamp and the two cylinders X and Y respectively, and the corresponding currents through the galvanometer.

Working volts of the lamp	Volts between cylinder X and the positive electrode P of the lamp. Position (1)	Milliampere current through the galvanometer connecting X and P	Volts between cylinder Y and the positive electrode P of the lamp. Position (3)	Milliampere current flowing through the galvanometer connecting Y and P
34	1	015	1	015
35	15	023		
36	20	031	3	045
37			4	060
38	6	095	7	11
39	8	126	9	14
40	1 05	166	1 1	17
41	1 3	206	1 6	25
42	1 8	285	2 0	31
43	2 1	333	2 8	44
44	2 6	412	3 5	55
45	3 0	476	4 5	77
46	3 6	571	5 8	92
47	4 2	659	7 2	1 12
48	4 9	791	8 8	1 39
49	5 6	889	10 9	1 72
50	6 2	984	13 6	2 15
51			15 1	2 39
52			18 6	2 95

§ 7. *Experiment 4.*—The magnitude of the current found on connecting any galvanometer between one of the cylinders and the positive electrode of the lamp was found to be [fol. 3046] dependent to some degree on the perfection of the vacuum. Lamp No. 3 when first made had not a very perfect vacuum. A series of measurements was, however, made with it, and the same repeated after re-exhaustion. The results are tabulated together below.

TABLE No. 6. *Lamp No. 3, Elliott galvanometer*

Table showing the relative values of the potential-difference between cylinder Y and the positive electrode for good and imperfect vacua in the case of lamp No. 3.

Working volts of the lamp	Very high vacuum in the lamp: Watts per candle-power taken up in carbon	Very high vacuum in the lamp: Volts between cylinder Y and positive electrode	Imperfect vacuum in the lamp: Watts per candle-power taken up in carbon	Imperfect vacuum in the lamp: Volts between cylinder Y and positive electrode
40	6 75	2 02	9 1	4 17
41	5 75	2 89	7 9	7 25
42	5 30	3 62	6 5	8 39
43	4 90	4 54	5 9	9 80
44	4 50	6 08	4 3	11 96
45	4 15	7 50	4 0	13 76
46	3 84	9 25	3 7	15 08
47	3 55	10 33	3 4	16 21
48	3 30	13 2	3 2	18 28
49	3 07	16 3	3 0	22 05
50	2 90	18 4	2 8	22 99
52	2 74	21 8	2 6	23 93
52	2 58	24 4	2 4	28 26

The imperfection of the vacuum is indicated by the higher watts per candle power absorbed at low voltages, and we see that at any given working pressure the potential-difference between the positive electrode and the cylinder Y embracing the top of the negative leg is *greater* when the vacuum is imperfect than when it is very good. The presence of residual air tends to bring down the potential of the embracing cylinder more nearly to that of the carbon at the point adjacent to it.

§ 8. *Experiment 5.*—A series of observations was next made in which the potential-difference between the middle plate and the positive electrode was determined by the aid of a condenser. If a condenser of capacity C in microfarads is charged to a potential of V volts and discharged through a ballistic galvanometer, we can determine the ballistic constant of the galvanometer. A second observation of a like nature in which the "throw" of the same galvanometer is observed when the same condenser is charged by contact with two points concerning which we require to know the potential-difference, gives us the means of calculating the electrostatic potential-difference in volts. A condenser of .987 microfarad capacity carefully determined was charged to a potential of 54 volts and discharged through a certain ballistic galvanometer having a needle whose periodic time

of vibration was about three seconds. The resulting "throw" of the galvanometer was 5° 30′. Hence a discharge of 54×.987 = 53.3 microcoulombs through the gal- [fol. 3047] vanometer produces a "throw" of 5° 30′. Neglecting a very small correction for the logarithmic decrement, in this case not of importance, we have for the ballistic constant R the value

$$53.3 = R \sin \tfrac{1}{2}(5^\circ\ 30') = R \times .04798;$$

hence

$$R = 1110.$$

The same condenser was then connected between the middle plate and positive electrode of lamp No. 4 and then discharged through the same ballistic galvanometer. The lamp was subjected to a working pressure of 39 volts as determined by a corrected voltmeter attached to the electrodes of the lamp. The charge of the condenser was sent through the ballistic galvanometer, and a "throw" of 4° obtained. If v is the potential-difference between the middle plate and positive electrode of the lamp, we have the following equation for v in terms of the ballistic constant and angle of "throw":

$$.987\ v = 1110 \sin 2^\circ$$
$$= 1110 \times .0349$$

or

$$v = \frac{111 \times 349}{987} = 39 \text{ nearly.}$$

The potential-difference between the middle plate and the positive electrode as determined by this method is therefore *exactly the same* as the potential-difference between the positive and negative electrodes of the lamp. In other words, when the filament is brought to full incandescence, the middle metal plate is brought to the same potential as the negative electrode of the lamp. This observation was repeated with several other lamps having middle plates in various positions and of various forms, and always with the same result, viz., that the potential of the middle plate when insulated is brought down nearly to that of the negative electrode.

9. *Experiment 6.*—In order to confirm the results obtained by the condenser method and to eliminate all the conditions which necessarily exist when we attempt to measure potential-difference galvanometrically, an electrostatic method of measuring the potential-difference at any instant

between the metal plate and the positive electrode of the lamp was next used. For this purpose a Kelvin multicellular electrostatic voltmeter was employed to determine the potential difference between the positive and negative electrodes of the lamp and between the positive electrode of the lamp and the middle plate, with the following results:

A lamp (No. 4) having the plate fixed between the carbon legs was raised to various working voltages and the potential-differences above mentioned taken.

[fol. 3048]

TABLE No. 7. *Lamp No. 4, Kelvin electrostatic voltmeter.*

Working volts of the lamp	Static potential-difference in volts between middle plate and positive electrode of the lamp
41	41
58.1	58.7
61.0	61.5

These observations confirm conclusively the previous results. The insulated metal middle plate is in this case brought to the *same potential* as the base of the negative leg of the carbon; and hence, on measuring electrostatically the potential-difference between that metal plate and the positive electrode of the lamp, we find it to be the same as the potential-difference between the two electrodes of the lamp.

10. *Experiment 7.*—In order to see if this was the case when the metal collecting-plate had a very small surface placed at some distance from the negative electrode of the lamp, the lamp called No. 1 was employed. In this lamp a platinum wire threaded through the turns of a double spiral 100 volt carbon lamp (see 11). The lamp was raised to various working voltages, and the electrostatic voltmeter employed to measure at the same time the static potential-difference between the positive electrode of the lamp and the platinum wire, with the following results:

TABLE No. 8. *Lamp No. 1, electrostatic voltmeter.*

Working volts of the lamp	Static potential-difference in volts between platinum wire and positive electrode of the lamp
62	53
79	75.5
97	85
118	107

The figures in the above Table No. 8 show that when the surface of the collecting-plate is very small and is placed some distance from the base of the negative leg of the carbon it is brought down only to the potential of some point (probably the nearest point) on the carbon conductor, and that therefore the potential-difference between the plate and positive electrode of the lamp is somewhat less than the potential-difference between the working terminals of the lamp. At the same time, however, the electrostatic voltmeter shows no measurable potential-difference between the negative terminal of the lamp and the platinum wire, and the most sensitive galvanometer between these points gives no indication of any current.

[fol. 3049] By means of the electrostatic voltmeter it was, however, ascertained that in those cases in which the metallic plate presented considerable surface (several square centimetres) and was placed so that some portion of it was not removed by more than a centimetre or two from the base of the negative leg of the carbon, it was brought down almost immediately to the potential of the negative terminal of the lamp. If the middle plate is placed at a little distance from the carbon loop then, on testing by the condenser method, it is found that the plate is not instantly brought down to the potential of the negative terminal, but that some few seconds have to elapse before this is the case.

11. A series of experiments was then undertaken in order to determine the effect of varying (1) the surface, and (2) the position of the metal plate in the bulb, and in these experiments the plate was sometimes of platinum and sometimes of aluminum. In all cases the vacuum was a very perfect one, any occluded gases in the plates being got rid of by special means.

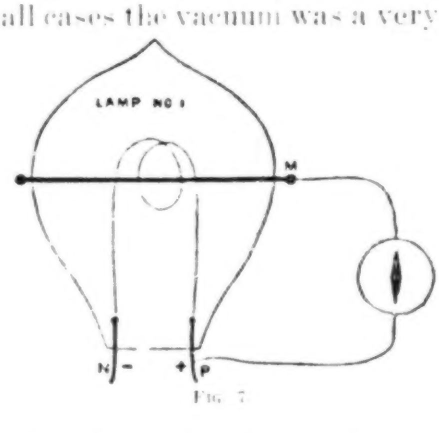


FIG. 7

Experiment 8.—A normal 100-volt carbon-filament lamp, having a carbon filament coiled in a spiral of two turns (see fig. 7) had a short stout platinum wire (.024 inch diam.) sealed across the bulb so as to thread through, without touching, the spirals of the carbon. The lamp at 100 volts took 1.54 am-

peres and gave an illumination of 40 candles, equivalent to a power absorption of 3.9 watts per candle-power. The vacuum was very good. This lamp will hereafter be called Lamp No. 1. As before, no current could be detected by a galvanometer when joined up between the platinum wire and the negative electrode, but when the galvanometer was connected between the platinum wire and the positive electrode of the lamp a current of some milliamperes was found passing through it. As in the case of lamp No. 4, this lamp was characterized by a great tendency to change suddenly the value of the current flowing through the galvanometer when the working volts on the lamp were kept perfectly constant. In the first series of observations the milamperemeter was employed to measure the current flowing between the positive electrode of the lamp and the platinum wire when it was connected between these points, and at and beyond a working-pressure of 90 volts or so the galvanometer would often jump suddenly from one reading to another, when the lamp working volts were kept perfectly constant.

In the following table, No. 9, are collected the results when the working pressure of the lamp was gradually raised from 80 to 100 volts:

[fol. 3050] TABLE No. 9.—*Lamp No. 1, milamperemeter*

Table showing the potential difference between the positive electrode and the platinum wire, and the current flowing through the galvanometer connecting them, for various voltages of the lamp.

Working volts of the lamp	Volts between platinum wire and positive electrode	Milliampere current through the galvanometer	Working volts of the lamp	Volts between platinum wire and positive electrode	Milliampere current through the galvanometer
80	1	016	92	1.7	270
"	2	032	"	2.4	281
82	3	048	93	1.9	302
83	2	032	"	2.6	413
84	4	064	94	3.2	509
86	4	064	"	9.4	1.49
"	7	114	95	4.9	78
87	5	080	96	5.8	92
88	8	127	97	7.1	1.13
"	9	142	98	8.3	1.32
90	1.0	159	99	8.9	1.41
"	1.3	206	100	8.6	1.37
91	1.4	222	"	10.5	1.64

These figures show that at any definite working electromotive force of the lamp the current between the positive electrode and the middle plate has very variable values, and that it suddenly changes from one value to another without any apparent reason, the working volts of the lamp remaining constant all the time.

If the surface of the collecting-plate is large, say several square centimetres, the potential-difference existing between it and the positive electrode is not found to be so much reduced by attempting to measure it with a galvanometer of about 6000 ohms resistance as it is when the collecting wire presents, as in this lamp No. 1, only a small total surface of about one square centimetre.

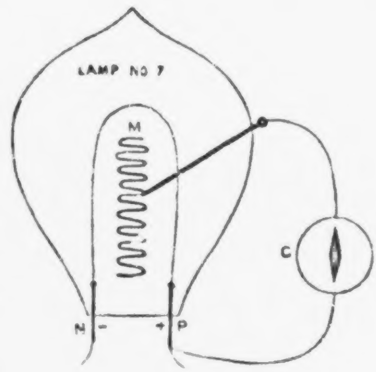


FIG. 8.

12. *Experiment 9.*—A horse-shoe carbon filament, taking 1.3 ampere of current at a working-pressure of 42.5 volts, had a middle plate made of a long piece of platinum wire bent up in a zigzag shape so as to form a rectangular-shaped grating (see fig. 8). The object of this was to ascertain whether a middle plate offering a surface pierced with many apertures was as effective in producing the current as a solid plate of about the same general outline. Practically it was found that this was the case.

The magnitude of the currents obtained at various working voltages are of the same magnitude approximately as in the case of a lamp like No. 4, that is to say some 3-4 milliamperes at full incandescence.

13. A set of experiments was then undertaken with the object of examining the special effect of varying the posi-[fol. 3051] tion of the middle plate, and a series of lamps was used in which platinum or aluminum plates held on platinum wires were placed in the lamp bulb, or in tubes opening into it, in various positions. These lamps are generally 50-volt lamps of usual type, and had single horse-shoe shaped filaments.

Experiment 10.—A lamp-bulb had a side tube blown on it (see fig. 9) and a plate about 6 centims. long and 1.5 centims. wide welded to a platinum wire was sealed into it. The platinum plate was placed vertically and edgeways in the

side tube and the side tube was in such a position that the plane of the platinum plate coincided with the plane of the horse-shoe filament. This lamp, called henceforth No. 2, when worked at 48 volts took 1.3 amperes of current and gave a light of 17.5 candles, equivalent to a power-consumption of 3.55 watts per candle-power. The vacuum was very good. In the case of this lamp the current between the positive electrode of the lamp and the platinum plate was found to be numerically very much smaller at the usual working pressure of the lamp than was found to be the case in those lamps in which the middle plate was placed between the carbon legs or in the form of a cylinder embracing the carbon.

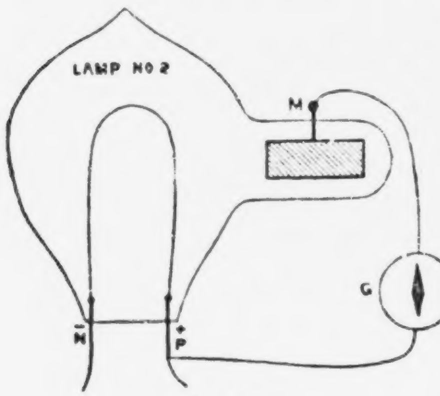


Fig. 9

The current obtained at any definite working voltage was considerably greater when the leg of the carbon nearest the plate was the *positive* leg than when it was the *negative* leg. A series of observations were taken using the lamp at different voltages and measuring with the Elliott galvanometer the potential-difference between the platinum plate and positive electrode of the lamp, and these results were as tabulated below in Table No. 10.

Table No. 10.—*Lamp No. 2, Elliott galvanometer*

Table showing the potential-difference between the platinum plate and the positive electrode of the lamp at various working voltages. Positive leg of carbon nearest the platinum plate.

Working volts of the lamp	Watts per candle-power	Volts between platinum plate and positive electrode	Working volts of the lamp	Watts per candle-power	Volts between platinum plate and positive electrode
43	6.26	088	48	3.55	190
44	5.80	111	49	3.32	236
45	4.42	144	50	3.12	289
46	4.10	156	51	2.94	352
47	3.80	172			

[fol. 3052] If we compare together the results obtained with this lamp No. 2, in which a plate is placed edgeways on and outside the carbon loop, with the results obtained in the case of lamp No. 3, in which the plates embraced the carbon in the form of cylinders, we see the difference produced by the change of position of the plate. Both these lamps, No. 2 and No. 3, are 48-volt lamps when working at normal incandescence. Referring to Table No. 7 in § 7, we see that for lamp No. 3 at 48 volts the voltage difference of the positive electrode and the platinum cylinders was respectively 13.2 and 18.3 volts as measured with the Elliott galvanometer, and this indicated a current of about 1.3 and 1.8 milliamperes flowing through the resistances from the positive lamp electrode to the metal plate; but in the case of lamp No. 2, at 48 volts the potential-difference between the platinum plate and the positive lamp electrode was only .2 volt, and this corresponded to a current of .03 milliampere nearly. Accordingly the current is greatly diminished when the collecting-plate is placed edgeways to and someway outside the loop of the carbon. At normal incandescence the current between the positive lamp electrode and the middle plate when joined by the galvanometer is about .03 or .04 milliampere when the *positive* leg of the carbon is nearest the middle plate, but only about .02 or .03 milliampere when the negative leg is nearest the plate.

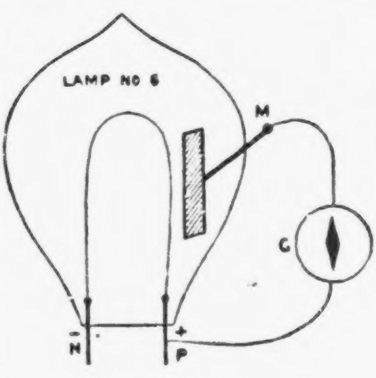


Fig. 10

14. *Experimental 1.*—In order to compare the previous results just given with those obtained when the collecting-plate was placed broadside to and yet outside the carbon loop, a lamp was made as in fig. 10 in which an aluminium plate was held on a platinum wire just outside one leg of the carbon and with its plane perpendicular to the plane of the horse-shoe.

The aluminium plate was 5 centims. long and 1 centim. wide, and distant from the nearest leg of the carbon about .5 centim. This lamp therefore differed from lamp No. 4 in having the plate outside the carbon loop rather than between the legs. It may be noticed that in this lamp the current here obtained by joining the positive lamp electrode to

the plate through a galvanometer was slightly greater when the leg nearest the plate was *negative* than when it was the positive leg, whereas in the case of lamp No. 2 it is just the reverse. This lamp exhibited also the same effect as lamp No. 4, in that the current flowing between electrode and plate is very liable to "jump" from one value to another even when the lamp is kept at constant volts. The following tabular result of the observations shows this. This lamp is called Lamp No. 6 and was a 50-volt horse-shoe carbon lamp, taking 1.33 amperes of current at a working electromotive force of 50 volts.

[fol. 3053] TABLE No. 11.—*Lamp No. 6, milamperemeter*

Table showing the potential-difference between the positive electrode of the lamp and the aluminium plate, and the current in milliamperes flowing through a galvanometer connecting them. Vacuum good.

Working volts of the lamp	Potential-difference of the positive electrode and plate in volts	Milliampere current through the galvanometer	Working volts of the lamp	Potential-difference of the positive electrode and plate in volts	Milliampere current through the galvanometer
32	.1	.016	46	3.8	.601
34	.3	.047	”	3.5	.555
36	.6	.065	”	14.1	2.23
37	.8	.126	47	3.8	.602
38	1.0	.158	”	16.2	2.57
39	1.2	.190	48	4.1	.650
40	1.7	.221	”	17.7	2.80
41	2.0	.317	49	4.2	.666
42	2.3	.364	”	18.3	2.90
43	2.8	.444	50	19.5	3.03
44	3.1	.491	”	20.0	3.17
45	4.0	.634	”	4.1	.650

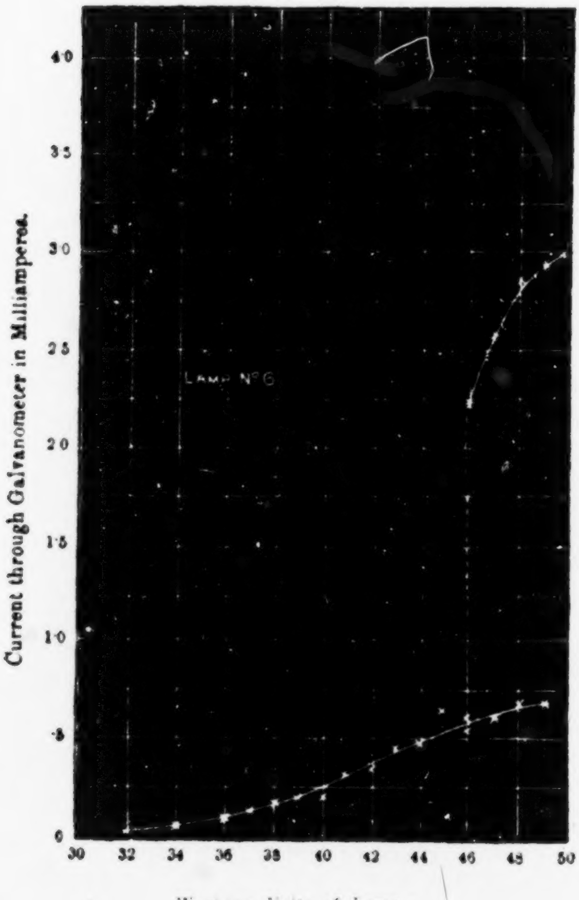
The results in Table No. 11 are plotted in curve No. 5.

[fol. 3054] This table shows that when the lamp is kept at a constant voltage the current through the galvanometer jumps from one value to another. The fluctuation of the current takes place when the negative leg of the carbon is the one farthest from the plate. When the leg adjacent to the aluminium plate is the negative one then the current is steady at any definite voltage of the lamp.

§ 15. From the above experiments it is clear that the current obtained when a galvanometer is connected between a

metallic plate and the positive electrode of the lamp is greater in proportion as the collecting-plate is larger and in proportion as it is brought into close proximity to the base

TABLE No. 11.—*Curve no. 5*



of the negative leg of the carbon. Also that a plate so placed is brought down to the potential of the negative electrode. It seemed desirable to see how far the removal of the collecting-plate to a great distance from the negative leg would influence these results, and experiments were accordingly tried with a tube of the form shown in fig. 11.

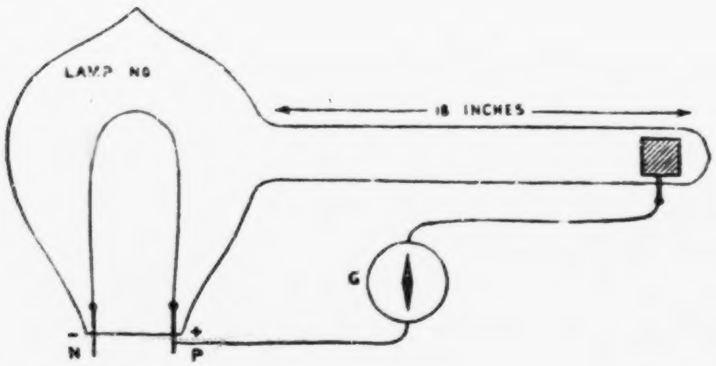


FIG. 11

Experiment 12.—In this case a glass tube about eighteen inches long and three-quarters of an inch in diameter was attached to a lamp bulb. The end of the glass tube farthest from the bulb was closed and an aluminium plate welded to a platinum wire was sealed in near this closed end. The plate had a length of about 3 centimetres and a width of about 1 centimetre. The tube formed an extension of the bulb space, and accordingly this arrangement formed a device by which a metal plate could be removed to a distance of some eighteen inches from the incandescent conductor contained in the bulb. On placing this lamp on a circuit and bringing the carbon to normal incandescence and connecting the terminals of the Elliott galvanometer respectively to the aluminium plate and the positive electrode of the lamp, a very small current was found to be passing through it, not, however, exceeding one ten-thousandth of a milliampere. When the galvanometer was joined in between the aluminium plate and the negative leg of the carbon no current whatever could be detected with this galvanometer, which was sufficiently sensitive to show one hundred-thousandth of a milliampere. We thus find that the removal of [fol.3055] the plate to a distance of some eighteen inches from the incandescent conductors practically extinguishes the phenomenon.

Experiment 13.—Another similar bulb was provided having a side tube blown on it of half the length, viz. about 9 inches long. At the end of this tube was placed a small

aluminium plate as before, and the tube was bent up about the middle at right angles (see fig. 12). When the carbon conductor in the bulb, which was that of an ordinary 50-volt 16 candlepower lamp, was rendered incandescent by being connected to a circuit of appropriate electromotive force, and the Elliott galvanometer connected in between the aluminium plate and the positive electrode of the lamp, a current of not more than about one twenty-thousandths of a milliampere was detected. The fact that the "Edison effect" was extinguished when the collecting-plate was placed at the extremity of an elbow-tube was first observed and recorded by Mr. Preece.

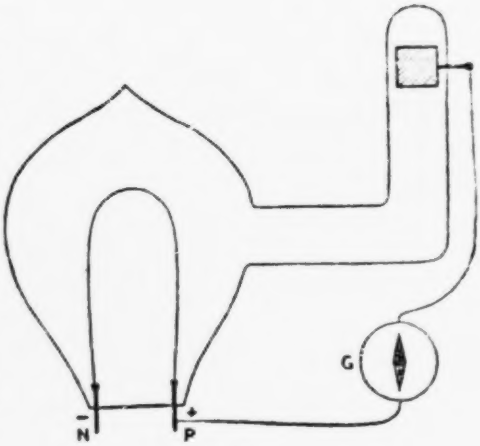


FIG. 12.

§ 16. The effect of position and size of the plate having been examined, the next step which naturally suggested

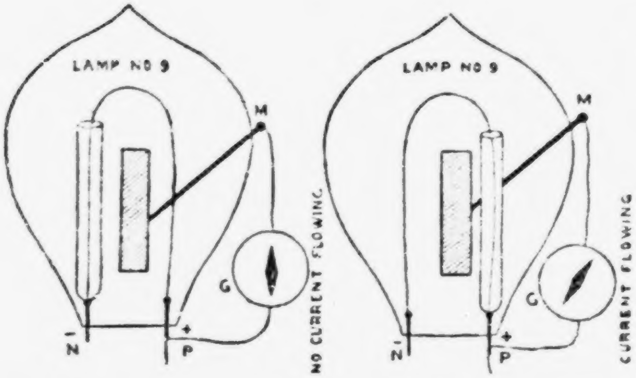


FIG. 13.

itself was to determine the effect of the different portions of the incandescent conductor in the production of it.

Experiment 14.—A lamp like No. 4 was provided, but in which one leg of the carboa was enclosed in a glass tube of the size of a quill. The glass tube was sealed on to the platinum wire and extended nearly up to the bend of the

carbon (see fig. 13). This lamp, called No. 9, was placed [fol. 3056] on the circuit in such a manner that the shielded leg was the *positive* leg, and a series of observations taken as usual of the current flowing through the milamperemeter when connected between the middle plate, placed between the carbon legs, and the positive electrode of the lamp. The results are as tabulated below in Table No. 12. The lamp took 1.25 ampere of current at a working electromotive force of 42 volts.

TABLE No. 12.—*Lamp No. 9, milamperemeter*

Table showing the potential difference between the middle plate and positive electrode of the lamp, and the current flowing through a galvanometer connecting them, when the *positive* leg of the carbon is shielded in a glass tube.

Working volts of the lamp	Potential-difference of middle plate and positive electrode in volts	Milampere current through galvanometer	Working volts of the lamp	Potential-difference of middle plate and positive electrode in volts	Milampere current through galvanometer
36	0.2	0.032	45	6.9	0.936
38	.3	.048	46	7.5	1.19
40	.95	.12	47	9.7	1.53
41	1.2	.19	48	12.3	1.96
42	1.8	.29	49	15.1	2.39
43	3.1	.49	50	19.1	3.03
44	4.2	.66	51	23.1	3.66

So far the results are quite normal, and if the results in the above Table No. 12 are compared with those in Table 2 for a similarly constructed lamp with no tubular shield, we find that the magnitude of the current flowing from the positive electrode to the middle plate is in the two cases very much the same. The lamp No. 9 was then placed on the circuit in such a manner that the leg shielded by the glass tube was the *negative* leg, and a similar series of observations of the current between the positive leg (now the uncovered leg) and the middle plate was made. The results were as follows in Table No. 13:

TABLES NO. 12 AND 13.—*Curve No. 6*

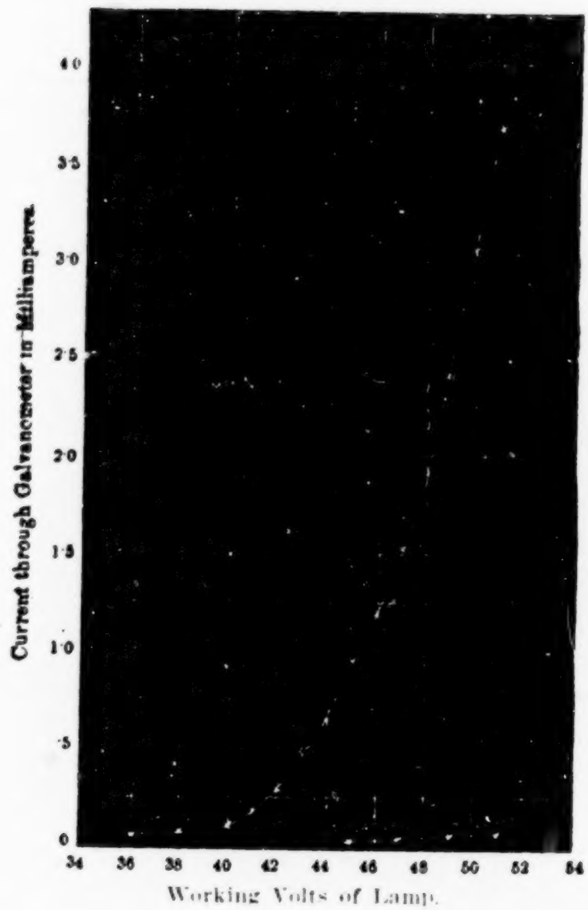


TABLE NO. 13.—*Lamp No. 9. Milamperemeter*

Table showing the potential-difference between the middle plate and positive electrode, and the current flowing through a galvanometer connecting them, when the *negative* leg of the carbon is shielded in a glass tube.

Working volts of the lamp	Potential-difference of middle plate and positive electrode in volts	Millampere current through galvanometer
45	10	016
47	15	024
49	25	039
51	30	044

On comparing the results in Table No. 13 and the previous one No. 12 we see what an immense reduction in the [fol. 3057] current flowing between the positive electrode and the middle plate is produced by shielding the *negative* leg. Hence the action in virtue of which the current is produced is greatly interfered with by enclosing or covering up the negative leg of the carbon. In this particular case at 51 volts the current between the positive electrode of the lamp anw the middle plate when the *negative* leg is covered up is only 1/83 of that which it is when the *positive* leg is covered up. The results in Tables Nos. 12 and 13 are plotted together in Curve No. 6.

17. The question remained to be settled whether the nature of the tubular screen in any way affected the results, and the glass tube was accordingly replaced by a metal (aluminium) tube and a lamp (No. 10) taken in which one of the carbon legs (see fig. 14) was surrounded by an aluminium cylinder extending nearly the whole length of the leg, and also a middle plate of aluminium was placed between the legs. Both the plate and the cylinder were held on platinum wires sealed through the glass. The lamp took 1.25 amperes of current at 41.5 volts.

[fol. 3058] *Experiment 15.*—The lamp was placed on a circuit so that the leg shielded by the aluminium cylinder was the *positive* leg. The milamperemeter was then connected between the positive electrode of the lamp and the middle plate, and the usual measurements made. It was found that the current "jumped" a good deal, and that high and low values of the galvanometer current occurred, even when the terminal voltage of the lamp was kept perfectly constant.

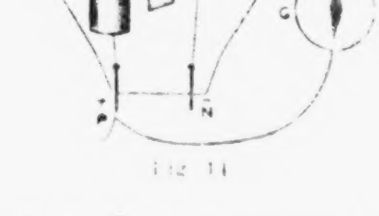


Fig. 14

The lamp was then reversed on the circuit so that the shielded leg was the *negative* one, all other arrangements remaining the same. The current now between the positive electrode and the middle plate was practically zero, at any rate too small to be measured with this galvanometer. Hence we see that shielding the negative leg, whether by glass or

a metallic cylinder, entirely cuts off the production of a current between the positive lamp electrode and the middle plate.

§ 18. *Experiment 16.*—Another series of experiments was made with the lamp No. 10 in which the galvanometer was connected between the positive electrode of the lamp and the aluminium cylinder (see fig. 15), the leg inside the cylinder being either the positive *or* the negative leg. In this case the middle plate remained unused and insulated

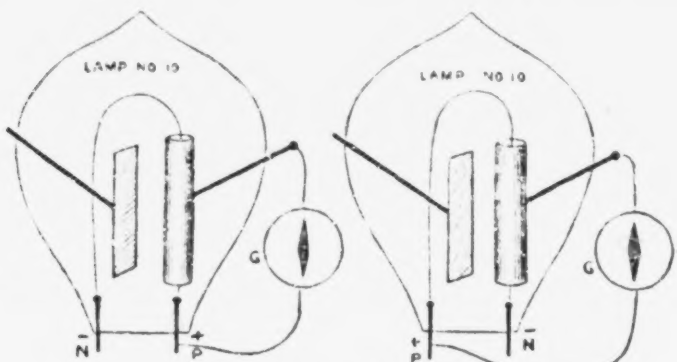


Fig. 15.

and acted as a shield between the cylinder and the carbon leg which was not contained in the cylinder.

It was found that when the cylinder surrounds the negative leg and its surface is, therefore, as much exposed to it as possible the current is a maximum, but that when it includes the positive leg the current is greatly diminished, both by reason of the fact that it opposes less surface to the negative leg, and also because the middle plate acts as a shield between it and the negative leg of the carbon.

[fol. 3059] § 19. *Experiment 17.*—In order finally to demonstrate that the negative leg of the carbon loop was the chief active agent in this production of a current between the middle plate and the positive electrode, a lamp like No. 4 was taken having a metal middle plate between the legs, and this middle plate had attached to it a mica screen (see fig. 16) a little larger than the plate, and so fixed by a loose rivet that it could be shaken in front of the plate so as to shield one side of it, or shaken on one side so as to fully expose the plate. This device was in fact a removable shield attached to one surface of the metal middle plate,

and when placed up against it, it shielded one surface from, and when jerked on one side it exposed that surface to, the carbon leg opposite to that surface. This lamp (called No. 5) was set on the circuit in the first place so that the leg of the carbon horse-shoe opposite to the mica-shielded side of the middle plate was the *positive* leg. If the carbon was brought up to an incandescence corresponding to about 3.5 or 4 watts per candlepower and the galvanometer connected between the positive electrode and the middle plate, then it was found that the effect on the galvanometer current which was produced by the interposition or withdrawal of the screen of mica between the positive leg and the plate was not very great. It reduced the current through the galvanometer from about .44 milliampere to .38 milliampere. If, however, the current flowing through the lamp carbon is reversed in direction so that the mica screen is interposed on that side of the middle metal plate which faces the *negative* leg, the result is very different. When the screen is down, the current flowing through the galvanometer from the positive electrode to the middle plate being as before .44 milliampere, the interposition of the mica screen on the side of the plate facing the negative leg reduced the current at once to zero. We find therefore, that the interposition of a mica screen between the middle plate and the negative leg reduces to zero the current flowing between the positive lamp electrode and the middle plate. As in all other lamps with a middle plate set exactly between the legs, the current through the galvanometer joining the middle plate and positive electrode is very liable to "jump" from a low to a higher value or *vice versa*. When the current has its higher value corresponding to any given voltage on the lamp terminals, the effect of screening is less marked, and although the interposition of the mica screen on the side facing the negative leg has an effect of reducing the current flowing through

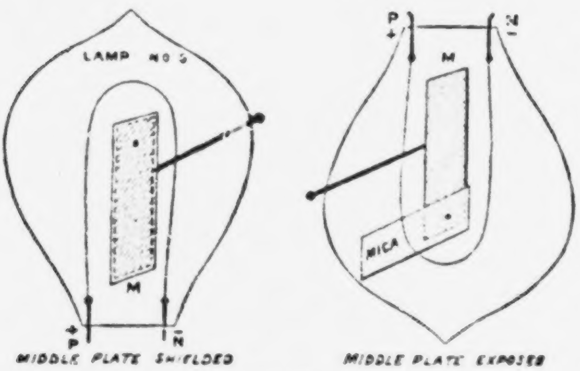


FIG. 16.

[fol. 3060] the galvanometer connected between the middle plate and positive electrode, it is not by any means reduced to zero.

§ 20. The foregoing experiments afford proof that the production of the current through a galvanometer joined between the positive electrode of the lamp and a metal plate placed somewhere in the vacuous bulb, is an effect due chiefly to the *negative* leg of the carbon, and that shielding the negative leg by enclosing it in a glass or metal tube, or covering with a mica screen that surface of the plate which is exposed to the negative leg, either quite prevents or greatly reduces the production of this current. The experiments also have shown that the magnitude of the current flowing through the galvanometer is increased by bringing the plate near to the base of the negative leg, or, better still, making the metal plate in the form of a cylinder and making this cylinder surround the *negative* leg near its base; and correspondingly it is diminished by removing it from the negative leg to a considerable distance, or by shielding this collecting-plate from the radiation from the negative leg of the carbon. The experiments with the condenser have also given evidence that when an insulated metal plate is sealed into a lamp, this plate is brought down either instantly or in a very short period of time to the potential of the *negative* leg near its base or to that of the *negative electrode* of the lamp. In looking for an explanation of these facts we are assisted by our previous knowledge that in carbon incandescence lamps, when working at an efficiency equivalent to 3 to 4 watts per candle-power, there is a gradual loss of carbon from all parts of the conductor. We know also that the carbon molecules which are projected from the conductor are thrown off into a space so highly vacuous that their mean free path is of a length comparable with, or greater than that of the dimensions of the glass bulb. The existence of molecular shadows in incandescence lamps[3] affords evidence that from intensely heated portions of the carbon conductor carbon molecules are projected in straight lines and move freely forward until they impinge against the glass. Commercial experience informs us that at and above a temperature corresponding to 3 watts per candle-power this loss of carbon becomes

[3] See J. A. Fleming, "Philosophical Magazine," August 1885, p. 141, vol. XIV.

very rapid and thins away the filament in one place, or generally reduces the diameter of the carbon conductor. Hence we have every reason to believe that when in a normal state of incandescence the carbon conductor in a lamp is throwing off in all directions carbon molecules, and that in the vacuum usually obtained the mean free path of these projected molecules is comparable with the dimensions of the vessel containing the conductor. The whole of the experiments which are detailed here seem to be capable of consistent interpretation if we may justifiably make the hypothesis that these carbon molecules or atoms so projected from the conductor when intensely heated by the current flowing through it are all *negatively* charged. Some of the observed [fol. 3561] facts seem to point to the conclusion that the molecules projected from the incandescent conductor, whether they are portions of the conductor itself or molecules of the residual gases, respectively carry away negative charges proportional in magnitude to the potential of the conductor at the point from which they are thrown off. They may, therefore, be looked upon as condensers of small but definite electrostatic capacity charged to the potential (negative) of that part of the incandescent conductor at which they separate from it. We have then in addition to explain how it comes to pass that there are few or no projected molecules charged positively. Two suggestions may be made on this point: either the radiation of matter is wholly confined to that half of the conductor at a negative potential or the incandescent carbon molecule thrown off from the heated conductor cannot retain a positive charge. There is much to lead to the conclusion that from *all parts* of the incandescent carbon conductor there is a constant radiation of matter carrying a negative electric charge. The nearer down to the negative electrode of the carbon we select our point of observation the greater is this molecular charge found to be. It will be convenient to denote this conveyance of electric charge by moving charged molecules by the term *molecular electro-*

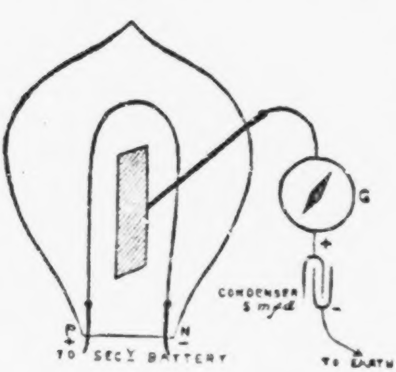


Fig. 1.

vection. We can then state the hypothesis thus—from all portions of the negative leg of the carbon loop a process of molecular electrovection is going on when the conductor is incandescent, the molecular charge being negative, and equal in potential to that of the point on the conductor from which it is projected.

21. On the assumption that a molecular shower of negatively charged atoms was being projected against the middle plate when the conductor of the lamp was incandescent it was considered probable that a positively charged conductor connected to the middle plate would be discharged, and this was found to be the case.

Experiment 18.—A lamp of the form of No. 4, having a middle metal plate placed between the carbon legs, had its middle plate connected to one terminal of the Elliott galvanometer. The other terminal of the galvanometer was connected to one terminal of a condenser of 5 microfarads capacity. The other terminal of the condenser was connected by a wire to the gas pipes of the laboratory. The lamp was actuated by secondary batteries (see fig. 17) not very well insulated. If the condenser was charged to a potential of 50 volts so that the plate next the galvanometer was *positively* charged, then this positive charge was *instantly discharged* when the carbon was rendered incandescent. If, however, the plate of the condenser in connexion with the middle plate through the galvanometer was [fol. 3062] charged *negatively* the condenser was not discharged when the lamp was illuminated by rendering its carbon incandescent. It is a very striking experiment to see a condenser charged with this amount (250 microcoulombs) of electricity instantly discharged when its positive coating is brought into connexion with the middle plate of such a lamp. The discharge may be brought about either by joining up the positive side of the condenser to the middle plate first, and then rendering the carbon of the lamp incandescent by switching on the lamp, or the lamp may be first of all illuminated and then the junction of the condenser effected. In both cases the middle plate when positively electrified is instantly discharged.

It was found that if the lamp carbon is rendered incandescent by a highly insulated secondary battery, then in order to produce the discharge, the plate of the condenser not in connexion with the middle plate, and which is *negatively* charged, must be somewhere connected with the bat

tery circuit. It does not matter, however, whether the wire from the negative side of the condenser is in connexion with the positive or the negative pole of the secondary battery actuating the lamp; all that is necessary is that the negative side of the condenser should be in conducting connexion with the circuit of the incandescent carbon. The experiment may be interpreted by considering that this negative charge of the condenser can escape out of the incandescent conductor and discharge across the highly vacuous space to the positively electrified cool middle metal plate; but that a positive charge cannot be discharged out of the hot conductor, or, which amounts to the same thing, a negative charge cannot discharge across from the cool metal plate to the incandescent carbon which is positively charged. We have then a unilateral conductivity exhibited by this highly vacuous space bounded by two electrodes one of which is incandescent and the other of which is cold. Negative electricity is discharged at once out of the hot surface but not out of the cold, and a negative discharge can take place from hot to cold but not *vice versâ*. When the discharge of a charged condenser is effected by connecting the positive plate, through a galvanometer, with a metal plate sealed into the lamp and the negative plate with the lamp circuit, and then switching on the lamp, there is a curious instant of delay before the discharge begins. When the metal plate is placed very near the negative leg of the carbon the discharge of the condenser is complete in one instant. This — the case when a lamp of the type No. 4 (fig. 18) is used. If, however, we employ a lamp of the type No. 2 (fig. 10), in which the metal plate is at some distance from the negative leg of the carbon, the discharge of the condenser is long drawn out and the electric charge in it is as it were tapped off slowly and not in one short sharp discharge.

Moreover this effect of discharging a condenser takes place only when the carbon is above a fair red heat. At brilliant incandescence and when the carbon is above a temperature corresponding to 3 watts per candle-power, the discharging power of a lamp of the type of No. 4 is very great. A condenser of 10 or 20 microfarads capacity [fol. 3063] charged to 50 volts is discharged instantly if its positive plate is connected to the metal plate placed not far from the negative end of the incandescent carbon conductor.

The foregoing results were confirmed with lamps of other types. Using, for instance, a lamp like No. 6 with the aluminum plate placed outside the carbon horse-shoe and near the leg, the same discharging power for positive electricity was found. It was not dependent on the direction of the current through the lamp carbon, although it seemed a little more vigorous when the leg nearest the plate was the negative leg. As above observed, the rate of discharge was much reduced when employing a lamp having the metal plate placed edgeways on to the carbon and some way from it, as, for instance, when employing a lamp of the form of No. 2.

§ 22. *Experiment 19.*—A series of experiments was in this case also tried to determine the effect of shielding the negatives leg of the carbon. The lamp No. 9 was employed, in which one leg of the carbon was enclosed in a glass tube connecting the positive plate of a charged condenser through a galvanometer with the middle plate of the lamp, and the negative plate of the condenser somewhere to the battery circuit; it was found that when the shielded leg of the carbon was the positive leg the condenser was discharged as before. If, however, the shielded leg or enclosed in the glass tube was made the negative leg, which could be done by reversing the current through the carbon conductor, then the condenser was not discharged when its positive plate was connected with the middle plate.

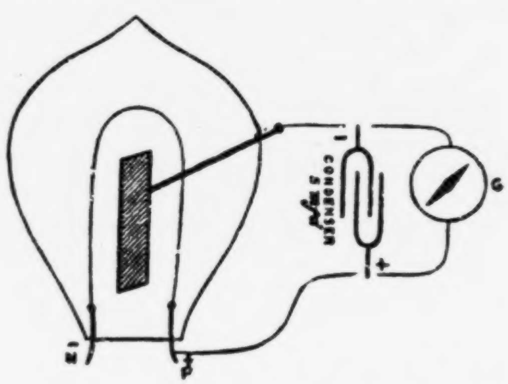


Fig. 18.

The same fact was less perfectly exhibited by employing the lamp with the middle plate having a removable mica shield on one side. We are thus able to assure ourselves that the active agent in producing this discharging effect upon a positively charged body connected to the middle plate is the negative leg of the carbon conductor. The experiments were varied in many ways, but all pointed to the conclusion that if a charged condenser is connected to two terminals, one of which is a metal plate and the other a

carbon conductor, both enclosed in a high vacuum but yet separated from each other by an inch or so of distance, the condenser is discharged instantly when the carbon terminal is rendered highly incandescent, provided that the negative plate of the condenser is in connexion with it.

23. If the condenser is left in contact with the middle plate under some circumstances, not only is it discharged if previously charged but is charged again in an opposite direction.

[Fol. 3064] *Experiment 20.* A condenser of 5 microfarads capacity perfectly discharged has its poles or terminals connected for one instant, one with the middle plate of No. 4 lamp and the other with the positive electrode of the lamp (see fig. 18). On removing it and testing it with the galvanometer G it is found that the condenser plate in connexion with the middle plate of the lamp has received a negative charge and the other plate of the condenser a positive charge.

If, however, the condenser is connected between the negative electrode of the lamp and the metal middle plate of the lamp, on insulating and testing it we find it has not the slightest charge.

It is very astonishing to see how instantly a condenser of very large capacity is charged when one pole of the condenser is connected to the middle plate and the other to the positive electrode of the lamp.

24. In considering the behaviour of the heated carbon electrode and the cool metal plate in their respective powers of discharging the positive or negative charge of the condenser, it seemed that the fundamental fact was the power of the heated surface to discharge negative electricity out of itself. Hence arose the question, how far the observed facts would be modified if the middle metal plate itself could be also heated. One way by which this might have been done would have been to have rendered this plate incandescent by heating it by radiant heat concentrated by means of a powerful mirror or lens. Some

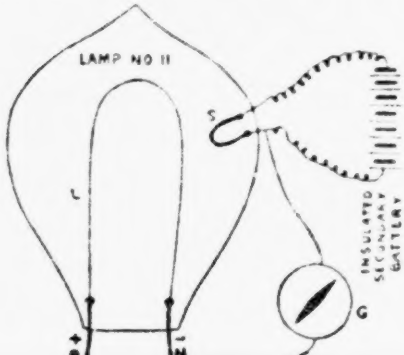


FIG. 19

experiments tried in this way were not satisfactory, and consequently a method was adopted in which a middle plate of carbon could be rendered incandescent electrically.

Experiment 21.—A vacuum tube was provided with two carbon conductors (see fig. 19), one the ordinary carbon filament L of a 50 volt lamp, and the other the small carbon S of a 4 volt lamp. The smaller carbon was sealed in the usual way through the glass and placed so as to stand symmetrically between the legs of the larger carbon loop.

The smaller carbon could be rendered incandescent by an insulated battery of fifteen secondary cells, appropriate resistance being introduced. The larger carbon also could be rendered incandescent by the proper electromotive force. If the smaller carbon was kept cold and employed simply as a third electrode or middle plate, all the phenomena previously described as happening with metal middle plates of aluminum or platinum took place. If the small (cold) carbon loop is connected through a galvanometer with the positive electrode of the larger carbon loop when this last is rendered incandescent by a current, we find as usual a [fol. 3065] current of a few milliamperes passing through the galvanometer from the postiive electrode of the larger carbon to the small carbon. If the small carbon (still cold) is connected through the galvanometer to the negative electrode of the larger carbon we get no current. This is the normal effect, and it is the same for a cold carbon conductor used as a middle plate as for a metal middle plate.

Experiment 22.—The next experiment consisted in making this small carbon incandescent by an insulated secondary battery, appropriate resistance being inserted so that the carbon was brought to the normal condition of temperature as indicated by its incandescence. When this was done the galvanometer was inserted between the positive electrode of the large carbon loop and one of the electrodes of the small carbon loop. A current was obtained as before. On connecting the galvanometer between the *negative* elec-

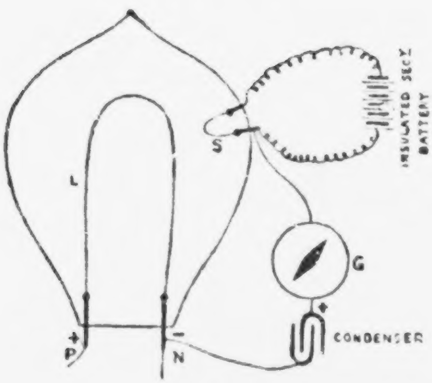


Fig. 20.

trode of the large carbon loop and one of the electrodes of the small carbon loop, a current of nearly equal value was now obtained. In this last experiment it was found to be immaterial whether the terminal of the galvanometer was joined to the positive or to the negative electrode of the small carbon loop. Hence we find that when the small carbon loop is not incandescent and is used as a middle plate or electrode, it is brought down together with the insulated battery attached to it to the same potential as the negative end of the large incandescent carbon, and we get as usual a current through a galvanometer connected between the positive electrode of the large incandescent carbon and any point on the small cold carbon, and no current between the negative electrode of the large hot carbon and the small cold one. On rendering the smaller carbon loop incandescent this is all changed. The smaller carbon, now hot, is not brought down to the potential of the negative ends of the larger carbon, and we get a current through a galvanometer connected between either positive or negative electrode of the large hot carbon and any point on the circuit of the smaller equally hot carbon.

25. *Experiment 23.*—With this same vacuum tube having double carbons, further experiments were performed on the discharging power of the hot and cold electrodes for positive and negative electricity. The two carbons could be rendered incandescent either simultaneously or singly by two sets of insulated secondary batteries attached to each respectively. For the sake of distinction we shall speak of the large carbon loop in this bulb as the L loop and the smaller one as the S loop. A condenser of 5 microfarads capacity (see fig. 20) was employed, which was charged to a potential of about 50 volts. When the positive plate of [fol. 3066] this charged condenser was attached to the carbon L and the negative side to the carbon S, then on making L incandescent by its own insulated battery and keeping S

cold, the condenser was found not to be discharged when insulated and tested by a galvanometer. If, however, the same charged condenser was connected in the same way to the two carbons and the carbon S, to which the negative side of the condenser was attached, was made incandescent, the condenser was instantly discharged. If the direction of the charging of the condenser was reversed the same rule was found to hold good. The condenser was discharged if the *negatively* charged plate of the condenser was connected to the *incandescent* carbon loop, but not if it was connected to the cold carbon loop. Beginning with the condenser charged and connecting it in between the two carbon loops, neither of them being incandescent, then the condenser was discharged instantly if that loop to which the *negatively* charged side of the condenser was attached was rendered incandescent, but not discharged if the loop to which the positive side of the condenser was connected was rendered incandescent. If both loops were rendered incandescent simultaneously the condenser in any case was discharged, but apparently at an accelerated rate. These experiments show again that if two carbon electrodes are sealed into a high vacuum, negative electricity escapes very freely out of either electrode if it is rendered incandescent, but that the escape or discharge of positive electricity is not in the same way facilitated by heating the positive electrode. Accordingly a highly vacuous space bounded by two carbon electrodes separated by a distance less than the mean free path of the gaseous molecule at that pressure, presents a unilateral conductivity when one of these electrodes is cold and the other highly incandescent. For if the hot electrode is connected to a negatively charged body and the cold electrode to a positively charged body, discharge takes place across the vacuous space, but if the charges are reversed then no discharge takes place. The negative charge can escape from the heated electrode but not from the cold one.

§ 26. *Experiment 24.*—The question of the apparent unilateral conductivity of the vacuous space bounded by a hot and a cold electrode was then further examined by the aid of the lamp No. 6 formerly used.

In this lamp an aluminum plate is sealed into the vacuum and placed just outside the carbon horse-shoe. If a sensitive galvanometer (the high resistence *Elliott* galvanometer) is joined up between the metal plate and the negative

electrode of the lamp, then, as in other cases when the lamp is in action, no current of a magnitude much greater than .0001 of a milliampere is detected. If a single Clark standard cell is inserted in the galvanometer circuit (see fig. 21) with its negative pole attached to the middle plate and its positive pole to the galvanometer terminal, the current is barely if at all increased. In this case the negative pole of the Clark cell is in connexion with a cold metal electrode and the *positive* pole is in connexion through the galvanometer with the incandescent carbon electrode, and under these circumstances the galvanometer detects no current [fol. 3067] flowing. The position of the Clark cell is now reversed, and it is joined up so that its positive pole is in connexion with the middle plate and its *negative* pole in connexion, through the galvanometer, with the incandescent carbon electrode. It is then found that a considerable current of some few milliamperes in magnitude is flowing through the galvanometer. The direction of this current in the ordinary way of speaking is *from* the negative electrode of the lamp through the galvanometer *to* the metal plate sealed into the bulb. We thus find that a negative current of electricity can be made to flow across the vacuous space between the incandescent carbon and the metal plate *from* the hot carbon *to* the cooler metal plate, but not in the reverse direction. The space presents an apparently unilateral conductivity.

27. *Experiment* 25.—The same experiment was repeated, only using instead of a Clark cell an insulated sec-

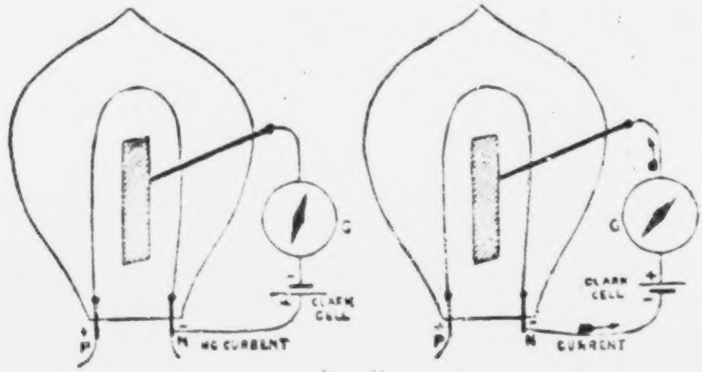


Fig. 21

ondary battery of 25 small cells. When the secondary battery (see fig. 21) was connected with its negative pole to the metal plate and its positive pole through the galvanometer

to the negative electrode of the carbon, no current greater than that found with the Clark cell similarly arranged was found; but if the secondary battery was reversed and joined up with its positive pole to the middle plate and its negative pole through the galvanometer to the negative electrode of the incandescent carbon, then so strong a current flowed through the galvanometer that it could not be measured without shunting-down the galvanometer considerably. The same experiments were repeated with the lamps having the zigzag wire as a metal plate, No. 7, and the same general results obtained. These experiments therefore show that in a circuit which consists partly of a galvanometer-wire and partly of a highly vacuous space bounded by two electrodes—one a metal plate and the other an incandescent carbon surface—the insertion of an electromotive force in one direction can produce a very sensible current, but that if the electromotive force is reversed then no current flows. The direction of the electromotive force must be such as to urge negative electricity from the hot surface to the cold across the vacuous space.

[fol. 3068] 28. *Experiment 26.*—In order to make use of different parts of the incandescent conductor as the electrode opposed to the metal plate, recourse was had to the lamp No. 3, with metal (aluminum) cylinders embracing without touching the carbon at two different places. These

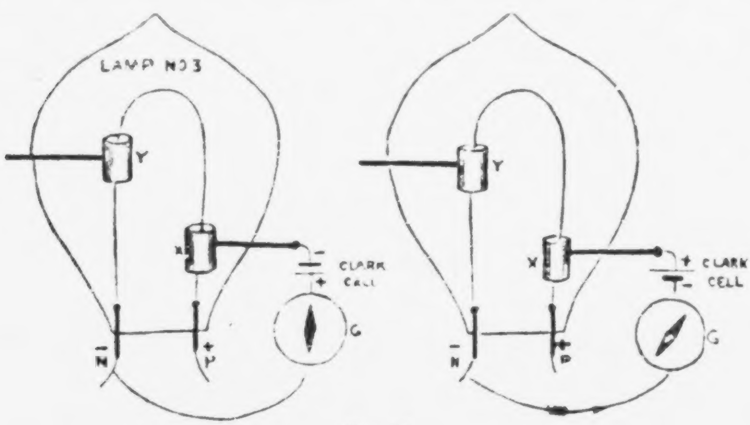


Fig. 22

cylinders, as before, we will call X and Y (see fig. 22). Cylinder X was the one near the base of the positive leg of the carbon, and cylinder Y was the one near the top of the negative leg.

When the galvanometer was connected between the negative electrode of the lamp and the cylinder X surrounding the lower part of the positive leg, no perceptible current was found to be passing when the carbon was rendered incandescent. On inserting a single Clark cell in series with the galvanometer so that the negative pole of the cell was in connexion with the cylinder X and the positive pole of the cell through the galvanometer in connexion with the negative electrode of the lamp, hardly any perceptible current was found to be passing (see fig. 22). The Clark cell was then reversed, connecting the positive pole of the cell to the cylinder X and the negative pole through the galvanometer to the negative electrode of the lamp. On bringing the lamp into action, a considerable current of several milliamperes was found to be passing in such a direction that a current of positive electricity was flowing across the vacuous space from the metal cylinder to the hot carbon, or a negative current from the hot carbon to the cooler metal cylinder. On switching off the lamp, there was a curious "kick" or "throw" of the galvanometer, indicating a sudden rush of current in the same direction as the steady current which the cell had been sending. These effects occurred also when the cylinder Y was employed, and the galvanometer with or without the cell in series joined in between the negative electrode of the lamp and the cylinder Y embracing the top part of the negative leg of the carbon (see fig. 22); but in the last case the steady current sent by the cell across the vacuous space between the cylinder and the hot carbon was only about a quarter as great in magnitude as when the cylinder X was employed. There was the same kind of [fol. 3069] "kick" of the galvanometer on breaking the lamp circuit. These experiments evidently showed that the highly vacuous space between the hot carbon traversed by its own current, which rendered it incandescent, and the insulated cylinder possessed a sort of unilateral conductivity, negative electricity from a separate source of small electromotive force being able to be forced through it from the hot carbon surface to the cooler metal surface, but not in an opposite direction.

29. In the above recorded experiments the carbon conductor was rendered incandescent by a unidirectional or continuous current in a highly perfect vacuum. In seeking for an hypothesis to connect them together, it became essen-

tial to ascertain how the effects would be modified if the vacuum was imperfect and if the current was alternating instead of continuous.

Experiment 27.—The fundamental experiment was therefore repeated with the normal type of lamp (No. 4), having a middle metal plate placed symmetrically between the legs of the carbon. A lamp of this type was set in action by an alternating current of suitable strength and of which the frequency was some 80 to 100 per second. On connecting the milamperemeter between *either* of the electrodes of the lamp and the middle plate, a *continuous* electric current was found flowing through the galvanometer. The direction of this current was such that positive electricity was found to flow from either lamp terminal to the middle plate of the lamp. In other words, a continuous current of negative electricity flowed out of the middle plate to one or other of the two terminals of the lamp, viz. to that terminal to which the other extremity of the galvanometer was joined. Hence, since in this case each leg of the carbon becomes in rapid succession positive *and* negative when the lamp is operated with an alternating current, the unilateral effect observed of a current flowing between the middle plate and the positive leg, when the current through the carbon is a continuous current, is here found to exist equally between the middle plate and *both* terminals of the lamp. This is only what might have been expected. The potential of the middle plate is then not the same as that of the base of either leg of the carbon, but something between the two depending upon the position of the plate.

§ 30. *Experiment 28.*—The effect of lowering the vacuum was also the subject of experiment. In a lamp with a highly perfect vacuum no current greater than about .0001 milliampere is observed when a very sensitive high-resistance galvanometer is joined up between the negative electrode of the carbon and the insulated middle plate, and, as we have seen the experiments with the electrostatic voltmeter showed that the plate was brought down under these circumstances to the potential of the base of the negative leg of the carbon. If, instead of employing a very perfect vacuum, a bad one is produced by imperfectly exhausting the lamp, then it is found that under these conditions the Elliott galvanometer indicates a not inconsiderable current of something approaching to a milliampere when joined in be-

tween the negative electrode of the lamp and the middle [fol. 3070] plate. Hence, when the vacuum is imperfect the equality in potential between the middle plate and the negative electrode is not maintained.

The direction of the current in this last case is such as to show that negative electricity is flowing through the galvanometer from the negative electrode of the lamp to the middle plate. In other words, negative charge is carried over from the plate to the positive leg of the carbon across the imperfectly vacuous space; and the means by which this is effected is the residual air. This seems to afford proof that the normal effect of the molecular electrovection of negative electricity from the negative leg is due to carbon molecules, and that the presence of residual air exhibits itself, when present beyond a certain amount, in producing an effect which the carbon molecular electrovection cannot produce.

31. *Experiment 29.*—It seemed very desirable to ascertain if the effect of molecular electrovection exists in the case of an incandescent platinum wire rendered vividly incandescent in a highly perfect vacuum. A bulb was accordingly constructed similar in every way to lamp No. 4, but having a platinum wire horse-shoe conductor and a platinum middle plate. When this wire was rendered highly incandescent by a continuous current, a sensitive galvanometer (the high resistance Elliott) showed a current of about one five-thousandth of a milliampere when connected between the positive electrode of the incandescent wire and the middle plate, but little or no current when connected between the negative electrode and the middle plate. This molecular *electrovection* current was thus very much less in magnitude than that observed in the case of the carbon filament lamps, but it is in the *same direction.* We are, however, enabled to state that at a condition of vivid incandescence just short of fusion a platinum wire *in vacuo* exhibits the same effects as a carbon filament, and that it can disturb the electrical condition of an insulated metal plate near it sealed into the same vacuum and tends to bring it down towards the potential of the negative end of that platinum wire.

On the hypothesis that all these effects are due to a scattering of negatively charged molecules from the incandescent conductor, we must affirm that the same process goes on in a platinum wire rendered incandescent in a vacuum,

only that the radiation of matter is far greater in the case of the incandescent carbon than it is in the case of the incandescent platinum.

§ 33. If a lamp is selected having an insulated plate fixed between the legs of the carbon filament it is found that under certain conditions the electric conductivity of the vacuous space between the plate and the negative leg is much affected by the presence of a magnetic field. If a galvanometer, preferably a movable coil galvanometer, having a resistance of about 500 or 600 ohms, is connected between the middle plate and the negative leg it will show but little current passing when the lamp is incandescent at normal temperature. If the volts on the lamp terminal are raised so that the filament is brought into a state of incandescence corresponding to about 2.5 or 3 watts per candle, then the [fol. 3071] galvanometer will show a small current passing through it. If then a horse-shoe magnet is held so as to create a magnetic field the direction of which is across the space between the plate and the negative leg, the current indicated by the galvanometer immediately decreases considerably. This happens irrespective of the direction of the field so long as it is across the direction of the line joining the negative leg and the middle plate. This indicates that the presence of this transverse field increases the resistance of the rarefied gas. The galvanometer current responds to the presence of the magnet in a manner which shows that the resistance to the flow of the current through the gas is increased by creating a magnetic field at right angles to the line of the current. The general fact that gaseous resistance is increased by such a transverse magnetic field has been already noted and described by Professor J. J. Thomson. The behaviour of bismuth as regards electrical resistance in a magnetic field is strikingly similar.

The "jumping" of the current from one value to a higher, which has been already mentioned, appears to be due to something equivalent to a sudden change in the resistance of the space between the negative leg and the middle plate when the lamp is in action and at high incandescence. The fact of sending a small current through this space seems to effect a change in the qualities of the rarefied gas as a conductor which makes it conduct better. There are certain after-effects in some cases which are strongly similar to the polarization of electrodes observed in the case of liquid elec-

trolysis, and which seem to point to the validity of the view that gaseous conduction is effected by a similar process.

The experiments also confirm the opinion of Professor J. J. Thomson that gases, or at least certain gases in a rarefied condition, are very good conductors, and they show that the greatest part of the obstacle to conduction through a vacuum-tube is at the electrodes and may be largely removed by heating the kathode to incandescence.

Discussion

Prof. S. P. Thompson said he would like to have some information as to the state of exhaustion of the lamps; whether this was such as is found in ordinary commercial lamps, or whether it more nearly approached that used by Crookes. A great change in the conductivity, &c., took place at an exhaustion slightly greater than that ordinarily found in incandescent lamps. It would be of interest to vary the size of the kathode, and to investigate whether the magnitude of the effects observed depended on the fall of potential per unit length along the filament. Another point was whether the position of the plate for which the effect was a minimum was the same for all lamps, or whether it changed with the volts and the length of the filament employed. Again, did the minimum occur at a certain fraction of the distance between the positive and negative leads, or, as was the case in some of the phenomena observed by Crookes, at a definite distance from either of the leads? These points might be [fol. 3072] investigated by means of a lamp with a straight filament, where the fall of potential per unit length along the filament could be made the same as with the loop-shaped filament but the fall of potential per unit length in the vacuum would be different. The author's proposed experiment of heating the kathode by concentrating on it the rays of a lamp did not seem to him (Prof. Thompson) to differ materially from Crookes' experiment in which an incandescent wire, heated by a current, was used as the kathode.

Mr. Skinner said that the heating of the kathode by means of a "burning-glass" could easily be carried out.

Mr. Blakesley pointed out that it would be quite possible to produce an increase of the current by means of a magnet.

Mr. Searle said that Prof. J. J. Thomson had shown that a magnet affected the conductivity of a gas.

Prof. Fleming, in his reply, said that no doubt the effects

were largely dependent on the vacuum in the lamps. The lamps employed were exhausted to the ordinary commercial vacuum. Since it was found that the "treating" was more worn off the negative leg of the filament, and that a screen placed between the legs of the filament was more blackened on the side turned towards the negative leg, it would appear that the particles of carbon were shot off from the negative leg, and hence perhaps the charge was carried by these carbon molecules.

[fol. 3073] DEFENDANT'S EXHIBIT P-1

Physikalische Zeitschrift—Oct. 20, 1904, pp. 680-81

Translation of Wehnelt Article

A Wehnelt (Erlangen), in reference to the exit of negative ions from incandescing metallic oxids and phenomena connected therewith.[1]

In a treatise with the same heading in Vol. 14, pp. 425-468 of the Annalen der Physik (1904) I have set forth a series of experiments and measurements which showed that certain metallic oxids, and in fact, especially the oxids of the earth alkali metals in an incandescing state, both under atmospheric pressure and also in a vacuum, emit numerous negative ions. (electrons)

In intimate connection with this quality stands the fact also discovered by me, that the cathode drop in a glimmer charge completely disappears on glowing oxid cathods even under the deepest pressures, provided that the current density (current strength per square centimeter of incandescing oxid surface) remains below a value depending upon the temperature and increasing with this. That current density at which a cathode drop begins to show I have called the limit current density. It attains, under high incandescence of the oxid, values up to three amperes.

I wish today to first bring before you some experiments which explain that which has been said above, and then to show you a practical application of incandescing oxide cathodes.

---

[1] Read in Division 2 on the 21st of Sept. Exhaustive literary references are to be found in Annalen der Physik Vol. 14, p. 425-468, 1904.

Emission of Negative Ions by Incandescing Metallic Oxids. A glass tube R (Fig. 1), exhausted to a moderate extent, contains a brass cylinder C in the axis of which [fol. 3074] there is situated a thin platinum wire D covered with CaO. The wire can be heated to high temperatures by the current of two accumulators A. If I connect the wire D with the one pole, the cylinder C through a galvanometer G with the other pole, of a source of current B, then there only flows a current through the tube if D is connected with the negative pole of B. The experiment shows consequently that only negative ions are emitted from the incandescing oxid.

If I take another tube, which is otherwise exactly similar, but which contains a platinum wire carefully cleaned, and heat the same to the same temperature as previously the wire covered with CaO, then the current is under an equally high negative charge of the wire only exceedingly weak, and in fact, only about 1/1000 of that in the former experiment.

Incandescing Metallic Oxids as Cathodes in Discharge Tubes. The tube R (Fig. 2) contains as cathode K a platinum sheet P covered with CaO which can be electrically heated red hot, and as an anode an iron wire A. The surface of the incandescing metallic oxid cathode amounting to several square centimeters, allows of sending through the tube considerable current strengths, even under deep pressures without there being present a cathode drop.

Since the anode drop constantly amounts to about 20 volts and the drop on the positive cells under strong currents and low pressures, as special measurements have shown, amounts to only one to two volts per centimeter, I can, by using the light conductor of 220 volts potential, send through the tube Fig. 2 currents of several amperes strength. The incandescing oxid cathodes furnish us consequently with a means of investigating the processes in the positive column with any gas whatever and under any pressures however deep, up to very high current strengths. The remarkable brightness of the positive strata under high current strength promises to be serviceable to the spectroanalytical investigation of gas spectra. Quartz windows on [fol. 3075] the tube would also make the ultra violet portion of the light of the strata accessible to investigation.

Weak Cathode Rays: If we exceed the limit current density either by increasing the current strength or decreasing the temperature of the incandescing oxid cathode, then we can impart to the cathode drop any desired value, and consequently produce cathode rays of any desired velocity.

The tube, Fig. 3, contains as cathode **K** a small platinum sheet P upon which there is located a small speck of calcium oxid.

A brass rod A serves as anode. If the sheet P is electrically brought to a glowing heat and the electrodes A, K, by throwing in a suitable resistance are connected with the light conductor of 220 volts potential, then the entire current goes only through the calcium oxid coating on the cathode sheet P, since here the cathode drop is much lower than on the clean platinum sheet, whereby there proceeds an intensely blue cathode beam of rays from the coating. By changing the temperature of the platinum sheet, there can be imparted to the cathode rays then any desired velocity, and this can then be measured according to well-known methods.

Application of Discharge Tubes with Glowing Metal Oxid Cathodes in Practice. If in an exhausted discharge tube R (Fig. 4)[1] we push one or several metallic electrodes A [fols. 3076-3077] close to the glowing metallic oxid electrode K (platinum sheet P covered with CaO) then the discharge potential, if A is anode and K is cathode, amounts to only about twenty volts. If we reverse the direction of current, so that now A is cathode and K is anode, the discharge potential now amounts to some thousands of volts, since under deep pressures the cathode drop on metals takes on exceedingly high values. If, therefore, we connect the electrodes A and K with an alternating source of current, the potential of which lies below the value which the cathode drop on the metallic electrode A has, then the tube acts as an electric valve, in that it allows to pass through only one phase of the alternating current. The tube (Fig. 4) can consequently serve for the purpose of transforming alternating current into pulsating direct current.

The maximum current strength to be sent through the tube (valve tube) depends as follows, from what has been

[1] The cathode K is assumed to be turned 90° as regards the plane of the picture.

said above, upon the size of the glowing oxid surface. The efficiency of the valve tube depends upon the working potential employed, and increases with this, since the tube up to the strongest allowable current strength, entirely independent of this, absorbs always only 20 volts potential. In applying a working potential of 120 volts alternating current, taking into consideration the consumption of watts for heating of the metal oxid cathode, the efficiency of the valve tube amounted to about 65%.

By using the well-known Graetz system of connection, both phases of the alternating current can be utilized. By using three metallic anodes, we can as with a Hewitt transformer, also transform rotary current into pulsating direct current.

Discussion.

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TABLE IV.—Selected Fusing and Boiling Points on the Proposed British Association Scale.

Substance.	F.P.	Substance.	B.P.
Tin	231.9	Aniline	184.1
Bismuth	269.2	Naphthalene	218.0
Cadmium	320.7	Benzophenone	305.8
Lead	327.7	Mercury	356.7
Zinc	419.0	Sulphur	444.5
Antimony	629.5	Cadmium	756
Aluminium	654.5	Zinc	916

My thanks are due to several Members of the Electrical Standards Committee of the British Association and others, who have kindly revised the proofs of this article.

LVIII. *On the Masses of the Ions in Gases at Low Pressures.* By J. J. THOMSON, *M.A., F.R.S., Cavendish Professor of Experimental Physics, Cambridge*.*

IN a former paper (Phil. Mag. Oct. 1897) I gave a determination of the value of the ratio of the mass, m, of the ion to its charge, e, in the case of the stream of negative electrification which constitutes the cathode rays. The results of this determination, which are in substantial agreement with those subsequently obtained by Lenard and Kaufmann, show that the value of this ratio is very much less than that of the corresponding ratio in the electrolysis of solutions of acids and salts, and that it is independent of the gas through which the discharge passes and of the nature of the electrodes. In these experiments it was only the value of m/e which was determined, and not the values of m and e separately. It was thus possible that the smallness of the ratio might be due to e being greater than the value of the charge carried by the ion in electrolysis rather than to the mass m being very much smaller. Though there were reasons for thinking that the charge e was not greatly different from the electrolytic one, and that we had here to deal with masses smaller than the atom, yet, as these reasons were somewhat indirect, I desired if possible to get a direct measurement of either m or e as well as of m/e. In the case of cathode rays I did not

* Communicated by the Author: read at the Meeting of the British Association at Dover.

see my way to do this; but another case, where negative electricity is carried by charged particles (*i.e.* when a negatively electrified metal plate in a gas at low pressure is illuminated by ultra-violet light), seemed more hopeful, as in this case we can determine the value of e by the method I previously employed to determine the value of the charge carried by the ions produced by Röntgen-ray radiation (Phil. Mag. Dec. 1898). The following paper contains an account of measurements of m/e and e for the negative electrification discharged by ultra-violet light, and also of m/e for the negative electrification produced by an incandescent carbon filament in an atmosphere of hydrogen. I may be allowed to anticipate the description of these experiments by saying that they lead to the result that the value of m/e in the case of the ultra-violet light, and also in that of the carbon filament, is the same as for the cathode rays; and that in the case of the ultra-violet light, e is the same in magnitude as the charge carried by the hydrogen atom in the electrolysis of solutions. In this case, therefore, we have clear proof that the ions have a very much smaller mass than ordinary atoms; so that in the convection of negative electricity at low pressures we have something smaller even than the atom, something which involves the splitting up of the atom, inasmuch as we have taken from it a part, though only a small one, of its mass.

The method of determining the value of m/e for the ions carrying the negative electrification produced by ultra-violet light is as follows:—Elster and Geitel (Wied. *Ann.* xli. p. 166) have shown that the rate of escape of the negative electrification at low pressures is much diminished by magnetic force if the lines of magnetic force are at right angles to the lines of electric force. Let us consider what effect a magnetic force would have on the motion of a negatively electrified particle. Let the electric force be uniform and parallel to the axis of x, while the magnetic force is also uniform and parallel to the axis of z. Let the pressure be so low that the mean free path of the particles is long compared with the distance they move while under observation, so that we may leave out of account the effect of collisions on the movements of the particles.

If m is the mass of a particle, e its charge, X the electric force, H the magnetic force, the equations of motion are:—

$$m\frac{d^2x}{dt^2} = \mathrm{X}e - \mathrm{H}e\frac{dy}{dt},$$

$$m\frac{d^2y}{dt^2} = \mathrm{H}e\frac{dx}{dt}.$$

Eliminating x we have :—

$$m\frac{d^2y}{dt^2} = \frac{He}{m}\left(Xe - He\frac{dy}{dt}\right).$$

The solutions of these equations, if x, y, dx/dt, dy/dt all vanish when $t=0$, is expressed by

$$y = \frac{Xm}{eH^2}\left\{\frac{e}{m}Ht - \sin\left(\frac{e}{m}Ht\right)\right\},$$

$$x = \frac{Xm}{eH^2}\left\{1 - \cos\left(\frac{e}{m}Ht\right)\right\}.$$

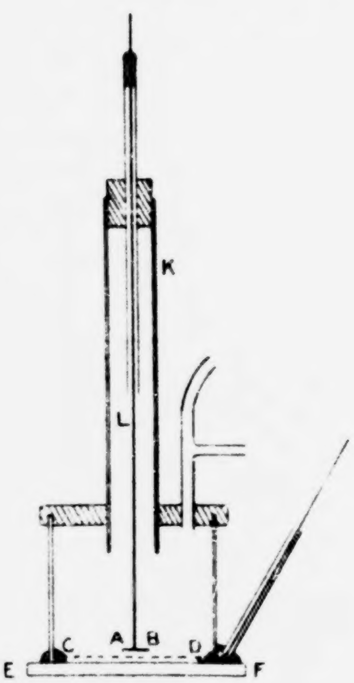
The equations show that the path of the particle is a cycloid, the generating circle of which has a diameter equal to $2Xm/eH^2$, and rolls on the line $x=0$.

Suppose now that we have a metal plate AB exposed to ultra-violet light, placed parallel to a larger metal plate CD perforated so as to allow the light to pass through it and fall upon the plate AB. Then, if CD is at a higher electric potential than AB, all the negatively electrified particles which start from AB will reach CD if this plate is large compared with AB, the particles travelling along the lines of electric force. Let us now suppose that a uniform magnetic force equal to H, and at right angles to the electric force, acts on the particles; these particles will now describe cycloids and will reach a distance $2Xm/eH^2$ from the place from which they start, and after reaching this distance they will again approach the plate. Thus if the plate CD is distant from AB by less than $2Xm/eH^2$, every particle which leaves AB will reach CD provided CD stretches forward enough to prevent the particles passing by on one side. Now the distance parallel to y through which the particle has travelled when it is at the greatest distance from AB is $\pi Xm/eH^2$: hence if CD stretches beyond AB by this distance at least, all the particles will be caught by CD and the magnetic field will produce no diminution in the rate of leak between AB and CD. If, on the other hand, the distance between the plates is greater than $2Xm/eH^2$, then a particle starting from AB will turn back before it reaches CD: it will thus never reach it, and the rate at which CD acquires negative electrification will be diminished by the magnetic force. Hence, if this view of the action of the magnetic field is correct, if we begin with the plates very near together and gradually increase the distance between them, we should expect that, at first with the plates quite close together, the rate at which CD received a negative charge would not be affected by the magnetic force, but as

soon as the distance between the plates was equal to $2X\,me\mathrm{H}^2$ the magnetic force would greatly diminish the rate at which CD received a negative charge, and would in fact reduce the rate almost to zero if all the negatively electrified particles came from the surface of AB. Hence, if we measure the distance between the plates when the magnetic force first diminishes the rate at which CD receives a negative charge, we shall determine the value of $2Xm/e\mathrm{H}^2$; and as we can easily determine X and H, we can deduce the value of m/e.

The way in which this method was carried into practice was as follows, the apparatus being shown in fig. 1.

Fig. 1.



AB is a carefully polished zinc plate about 1 centim. in diameter, while CD is a grating composed of very fine wires crossing each other at right angles, the ends being soldered into a ring of metal; the wires formed a network with a mesh about 1 millim. square. This was placed parallel to AB on the quartz plate EF, which was about 1 millim. thick. The grating was very carefully insulated. The system was enclosed in a glass tube which was kept connected with a mercury-pump provided with a McLeod gauge. The ultra-violet light was supplied from an arc about 3 millim. long between zinc terminals. The induction-coil giving the arc was placed in a metal box, and the light passed through a window cut in the top of the box; over this window the quartz base of the vessel was placed, a piece of wire gauze connected with the earth being placed between the quartz and the window. The plate AB was carried by the handle L which passed through a sealing-wax stopper in the tube K. The magnet used was an electromagnet of the horseshoe type. The magnetic force due to the magnet was determined by observing the deflexion of a ballistic galvanometer when an exploring coil, of approximately the same vertical dimen-

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sion as the distance between the plates AB and CD, was withdrawn from between its poles. The coil was carefully placed so as to occupy the same part of the magnetic field as that occupied by the space between AB and CD when the magnet was used to affect the rate of leak of electricity between AB and CD. In this way the intensity of the magnetic field between the poles of the magnet was determined for a series of values of the current through the magnetizing-coils of the electromagnet ranging between 1 and 1·5 amperes, and a curve was drawn which gave the magnetic force when the magnetizing-current (observed by an amperemeter) was known.

The pressure of the gas in the tube containing the plate was reduced by the mercury-pump to 1/100 of a millim. of mercury. As the mean free path of hydrogen molecules at atmospheric pressure and 0° C. is $1{\cdot}85 \times 10^{-5}$ centim. (Emil Meyer, *Kinetische Theorie der Gase*, p. 142), and of air 10^{-5} centim., the mean free paths of these gases at the pressure of 1/100 of a millim. of mercury are respectively 11 and 7·6 millim., and are consequently considerably greater than the greatest distance, 1 millim., through which the electrified particles have to travel in any of the experiments. These are the free paths for molecules of the gas; if, as we shall see reason to believe, the actual carriers of the negative electrification are much smaller than the molecules, the free paths of these carriers will be larger than the numbers we have quoted.

The rate of leak of negative electricity to CD when AB was exposed to ultra-violet light was measured by a quadrant-electrometer. The zinc plate was connected with the negative pole of a battery of small storage-cells, the positive pole of which was put to earth. One pair of the quadrants of the electrometer was kept permanently connected with the earth, the other pair of quadrants was connected with the wire gauze CD. Initially the two pairs of quadrants were connected together, the connexion was then broken, and the ultra-violet light allowed to fall on the zinc plate; the negative charge received by the wire gauze in a given time is proportional to the deflexion of the electrometer in that time. By this method the following results were obtained: when the difference of potential between the illuminated plate and the wire gauze was greater than a certain value depending upon the intensity of the magnetic force and the distance between AB and CD, no diminution in the deflexion of the electrometer was produced by the magnetic field, in fact in some cases the deflexion was just a little greater in the magnetic field. The theory just given indicates that the deflexion

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ought to be the same: the small increase (amounting to not more than 3 or 4 per cent.) may be due to the obliquity of the path of the particles in the magnetic field, causing more of them to be caught by the wires of the grating than would be the case if the paths of the particles were at right angles to the plane of the gauze. When the difference of potential is reduced below a certain value, the deflexion of the electrometer is very much reduced by the magnetic field; it is not, however, at once entirely destroyed when the potential-difference passes through the critical value. The simple theory just given would indicate a very abrupt transition from the case when the magnetic force produces no effect, to that in which it entirely stops the flow of negative electricity to CD. In practice, however, I find that the transition is not abrupt: after passing a certain difference of potential the diminution in the electric charge received by CD increases gradually as the potential-difference is reduced, and there is not an abrupt transition from zero effect to a complete stoppage of the leak between AB and CD. I think this is due to the ionization not being confined to the gas in contact with the illuminated plate, but extending through a layer of gas whose thickness at very low pressures is quite appreciable. The existence of a layer of this kind is indicated by an experiment of Stoletow's. *Stoletow found that the maximum current between two plates depended at low pressures to a considerable extent upon the distance between the plates, increasing as the distance between the plates was increased. Now the maximum current is the one that in one second uses up as many ions as are produced in that time by the ultra-violet light. If all the ions are produced close to the illuminated plate, increasing the distance between the plates will not increase the number of ions available for carrying the current; if, however, the ions are produced in a layer of sensible thickness, then, until the distance between the plates exceeds the thickness of this layer, an increase in the distance between the plates will increase the number of ions, and so increase the maximum current. If this layer has a sensible thickness, then the distance d which has to be traversed by the ions before reaching the gauze connected with the electrometer ranges from the distance between the plates to the difference between this distance and the thickness of the layer. The first ions to be stopped by the magnetic field will be those coming from the surface of the illuminated plate, as for these d has the greatest value: hence we may use the equation

$$d = \frac{2Xm}{eH^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

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if d represents the distance between the plates, X the value of the electric field when the rate of leak first begins to be affected by the magnetic force H. Assuming that the field is uniform,

$$X = V/d,$$

where V is the potential-difference between the plates; and equation (1) becomes

$$d^2 = \frac{2Vm}{eH^2}$$

The negative ions travelling between the plates will disturb to some extent the uniformity of the field between the plates; but if the intensity of the ultra-violet light is not too great, so that the rate of leak and the number of ions between the plates is not large, this want of uniformity will not be important. A calculation of the amount of variation due to this cause showed that its effect was not large enough to make it worth while correcting the observations for this effect, as the variation in the intensity of the ultra-violet light was sufficient to make the errors of experiments much larger than the correction.

The following is a specimen of the observations:—

Distance between the plates ·29 centim.

Strength of magnetic field 164. Pressure 1/100 millim.

Potential-difference between Plates, in volts.	Deflexion of Electrometer in 30 secs.	
	Magnet off.	Magnet on.
240	180	190
120	160	165
80	160	140
60	150	75

These observations showed that the critical value of the potential-difference was about 80 volts. A series of observations were then made with potential-differences increasing from 80 volts by 2 volts at a time and it was found that 90 volts was the largest potential-difference at which any effect due to the magnet could be detected. The results of a number of experiments are given in the following table:—

d (in cm.)	H.	V in absolute measure.	e/m.
·18	170	40×10^8	$8·5 \times 10^6$
·19	170	30×10^8	$5·8 \times 10^6$
·20	181	46×10^8	$7·0 \times 10^6$
·29	167	84×10^8	$7·1 \times 10^6$
·29	164	90×10^8	$7·6 \times 10^6$
·30	160	86×10^8	$7·4 \times 10^6$
·45	100	80×10^8	$7·9 \times 10^6$

giving a mean value for e/m equal to $7·3 \times 10^6$. The value I found for e/m for the cathode rays was 5×10^6; the value found by Lenard was $6·4 \times 10^6$. Thus the value of e/m in the case of the convection of electricity under the influence of ultra-violet light is of the same order as in the case of the cathode rays, and is very different from the value of e/m in the case of the hydrogen ions in ordinary electrolysis when it is equal to 10^4. As the measurements of e, the charge carried by the ions produced by ultra-violet light to be described below, show that it is the same as e for the hydrogen ion in electrolyis, it follows that the mass of the carrier in the case of the convection of negative electricity under the influence of ultra-violet light is only of the order of 1/1000 of that of the hydrogen atom. Thus with ultra-violet light, as with cathode rays, the negative electrification at low pressures is found associated with masses which are exceedingly small fractions of the smallest mass hitherto known—that of the hydrogen atom.

I have examined another case in which we have convection of electricity at low pressures by means of negatively electrified particles—that of the discharge of electricity produced by an incandescent carbon filament in an atmosphere of hydrogen. In this case, as Elster and Geitel (Wied. *Ann.* xxxviii. p. 27) have shown, we have negative ions produced in the neighbourhood of the filament, and the charge on a positively electrified body in the neighbourhood of the filament is discharged by these ions, while if the body is negatively electrified it is not discharged. If the filament is negatively, and a neighbouring body positively electrified, there will be a current of electricity between the filament and the body, while there will be no leak if the filament is positively and the body negatively electrified. Elster and Geitel (Wied.

Ann. xxxviii. p. 27) showed that the rate of leak from a negatively electrified filament was at low pressures diminished by the action of the magnetic field. On the theory of charged ions, the effect of the magnet in diminishing the rate of leak could be explained in the same way as the effect on the convection due to ultra-violet light. A series of experiments were made which showed that the effects due to the magnetic field were consistent with this explanation, and led to a determination of e/m for the carriers of the negative electricity.

The apparatus was of the same type as that used in the preceding experiments. The wire gauze and the zinc plate were replaced by two parallel aluminium disks about 1·75 centim. in diameter; between these disks, and quite close to the upper disk, there was a small semicircular carbon filament which was raised to a red heat by the current from four storage-cells. The carbon filament was placed close to the axis of the disks; the object of the upper disk was to make the electric field between the disks more uniform. The lower plate was connected with the electrometer. The plates and filaments were enclosed in a glass tube which was connected with a mercury-pump, by means of which the pressure, after the vessel had been repeatedly filled with hydrogen, was reduced to ·01 millim. of mercury. Great difficulty was found at first in getting any consistent results with the incandescent carbon filament: sometimes the filament would discharge positive as well as negative electricity; indeed sometimes it would discharge positive and not negative. Most of these irregularities were traced to gas given out by the incandescent filament; and it was found that by keeping the filament almost white-hot for several hours, and continually pumping and refilling with hydrogen, and then using the filament at a much lower temperature than that to which it had been raised in this preliminary heating, the irregularities were nearly eliminated, and nothing but negative electrification was discharged from the filament. When this state was attained, the effect of magnetic force showed the same characteristics as in the case of ultra-violet light. When the difference of potential between the filament and the lower plate was small, the effect of the magnetic force was very great, so much so as almost to destroy the leak entirely; when, however, the potential-difference exceeded a certain value, the magnetic force produced little or no effect upon the leak. An example of this is shown by the results of the following experiment:—

The distance between the carbon filament and the plate connected with the electrometer was 3·5 millim., the strength of the magnetic field 170 C.G.S. units.

Difference of Potential between wire and plate, in volts.	Leak in 5 seconds.		Ratio of leaks
	Without magnetic field.	With magnetic field.	
40	43	1	·023
80	170	50	·20
120	300	250	·83
140	345	345	1·0
160	400	430	1·07

Taking 140 volts as the critical value of the potential-difference, we find by equation (1) that

$$\frac{e}{m} = 7\cdot8 \times 10^6.$$

The results of this and similar experiments are given in the following table; V denoting the critical potential-difference in C.G.S. units, and H the magnetic force:

d.	V.	H	*e/m*.
·35	140×10^8	170	$7\cdot8 \times 10^6$
·35	220×10^8	220	$7\cdot5 \times 10^6$
·35	170×10^8	170	$9\cdot6 \times 10^6$
·35	130×10^8	170	$7\cdot2 \times 10^6$
·35	120×10^8	120	$11\cdot3 \times 10^6$

giving $8\cdot7 \times 10^6$ as the mean value of e/m. This value does not differ much from that found in the case of ultra-violet light. In the case of the incandescent filament the ions are only produced at a small part of the plate, and not over the whole surface as in the case of ultra-violet light, so the conditions do not approximate so closely to those assumed in the theory. We conclude that the particles which carry the negative electrification in this case are of the same

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nature as those which carry it in the cathode rays and in the electrification arising from the action of ultra-violet light.

The unipolar positive leak which occurs from an incandescent platinum wire in air or oxygen, and in which the moving bodies are positively electrified, was found not to be affected by a magnetic field of the order of that used in the experiments on the negative leak. This had already been observed by Elster and Geitel (Wied. *Ann.* xxxviii. p. 27).

On the theory of the effect given in this paper, the absence of magnetic effect on the positively charged carriers indicates that e/m is much smaller or m/e much larger for the positive ions than it is for the negative. I am engaged with some experiments on the effect of the magnetic field on the convection of electricity by positive ions, using very strong magnetic fields produced by a powerful electromagnet kindly lent to me by Professor Ewing. From the results I have already got, it is clear that m/e for the positive ions produced by an incandescent wire must be at least 1000 times the value for the negative ions, and this is only an inferior limit.

The positive and negative ions produced by incandescent solids show the same disproportion of mass as is shown by the positive and negative ions in a vacuum-tube at low pressures.

W. Wien (Wied. *Ann.* lxv. p. 440) and Ewers (Wied. *Ann.* lxix. p. 187) have measured the ratio of m/e for the positive ions in such a tube, and found that it is of the same order as the value of m/e in ordinary electrolysis; Ewers has shown that it depends on the metal of which the cathode is made. Thus the carriers of positive electricity at low pressures seem to be ordinary molecules, while the carriers of negative electricity are very much smaller.

Measurement of the Charge on the Ion produced by the Action of Ultra-Violet Light on a Zinc Plate.

This charge was determined by the method used by me to measure the charge on the ions produced by the action of Röntgen rays on a gas (Phil. Mag. Dec. 1898); for the details of the method I shall refer to my former paper, and here give only an outline of the principle on which the method is based. Mr. C. T. R. Wilson (Phil. Trans. 1898) discovered that the ions produced by ultra-violet light act like those produced by Röntgen rays, in forming nuclei around which water will condense from dust-free air when the supersaturation exceeds a certain definite value.

Suppose, then, we wish to find the number of ions produced by ultra-violet light in a cubic centimetre of air. We cool the air by a sudden expansion until the supersaturation

produced by the cooling is sufficient to form a cloud round the ions: the problem of finding the number of ions per cub. centim. is now reduced to finding the number of drops per cub. centim. in this cloud. We can do this in the following way:—If we know the amount of the expansion we can calculate the amount of water deposited per cub. centim. of the cloud; this water is deposited as drops, and if the drops are of equal size, the number of drops per cub. centim. will be equal to the volume of water per cub. centim. divided by the volume of one of the drops. Hence, if we know the size of the drops, we can calculate the number. The size of the drops in the cloud was determined by observing v, the velocity with which they fall under gravity, and then deducing a, the radius of the drop, by means of the equation

$$v = \frac{2}{9}\frac{ga^2}{\mu},$$

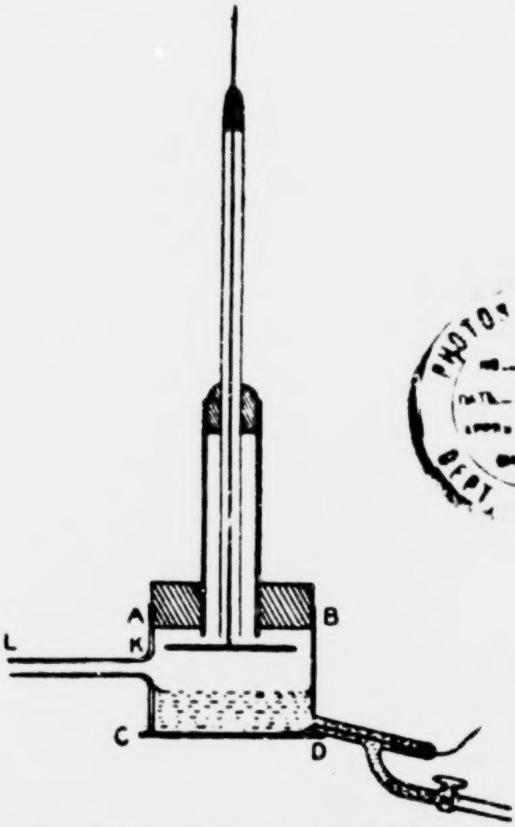
where μ is the coefficient of viscosity of the gas through which the drop falls.

In this way we can determine n the number of ions per cub. centim.: if e is the charge on an ion, u the velocity with which it moves under a known electric force, the quantity of electricity which crosses unit area in unit time under this force is equal to neu. We can determine this quantity if we allow the negative ions to fall on a plate connected with a condenser of known capacity and measure the rate at which the potential falls. We thus determine the product neu, and we already know n; u has been determined by Mr. Rutherford (Proc. Camb. Phil. Soc. ix. p. 401); for air at atmospheric pressure u is proportional to the potential gradient, and when this is one volt per centim., u is 1·5 centim. per second; for hydrogen at atmospheric pressure u is 4·5 centim. per second for the same potential gradient. Hence, as in the known product neu we know n and u, we can deduce the value of e the charge on the ion.

There are some features in the condensation of clouds by ultra-violet light which are not present in the clouds formed by the Röntgen rays. In the first place, the cloud due to the ultra-violet light is only formed in an electric field. When there is no electric field, the ions remain close to the surface of the illuminated plate, and are not diffused through the region in which the cloud has to be formed; to get the negative ions into this region we must electrify the plate negatively; when this is done, expansion produces a cloud. Again, if the ultra-violet light is very strong, Mr. C. T. R. Wilson has shown (Phil. Trans. 1899) that large nuclei are produced

in the gas through which the light passes; these are distinct from those produced near a metal plate on which the light falls, and they can produce a cloud with very little supersaturation; these nuclei are not ions, for they do not move in an electric field, and the drops formed round these nuclei ought therefore not to be counted in estimating the number of negative ions. For this reason it is necessary to use ultra-violet light

Fig. 2.



of small intensity, and there are in addition other reasons which make it impossible to work with strong light. I found when working with the ions produced by Röntgen rays, that it was impossible to get good results unless the rays were weak and the clouds therefore thin. If the rays were strong, one expansion was not sufficient to bring down all the ions by the cloud; sometimes as many as five or six expansions were required to remove the ions from the vessel. Another

reason why the strong rays do not give good results is that there are slight convection-currents in the vessel after the expansion, for the walls of the vessel are warmer than the gas; this gives rise to convection-currents in the gas, the gas going up the sides and down the middle of the vessel. The velocity of the convection-current is added on to the velocity of the ions due to gravity; and if the velocity of the ions is very small, as it is when the rays are strong and the drops numerous, a very small convection-current will be sufficient to make the actual rate of fall of the drops very different from that of a drop of the same size falling through air at rest. All the reasons are operative in the case of ultra-violet light, and it is only when the intensity of the light is small that I have got consistent results.

The vessel in which the expansion took place is shown in fig. 2. AB is a glass tube about 3·6 cm. in diameter; the base CD is a quartz plate about ·5 cm. thick; on the top of this there is a layer of water in electrical connexion with the earth about 1 cm. in thickness; the illuminated zinc plate was 3·2 cm. in diameter, and was 1·2 cm. above the surface of the water. The ultra-violet light was produced by an arc about ·3 cm. long, between zinc terminals connected with an induction-coil; the arc was about 40 cm. below the lower face of the quartz plate. The space between the zinc plate and the water surface was illuminated by an arc-light so as to allow the rate of fall of the drops to be accurately measured. The tube LK connected this vessel with the apparatus used in the previous experiments; a figure of this is given in the Phil. Mag. Dec. 1898.

To observe the current of electricity through the gas, the illuminated plate was connected with one pair of quadrants of an electrometer, the other pair of quadrants being kept connected with the earth. The capacity C of the system, consisting of the plate, connecting wires and quadrants of the electrometer, was determined. The plate was then charged to a negative potential, and the deflexion of the electrometer-needles observed. The induction-coil was now set in action, and the ultra-violet light allowed to fall on the zinc plate; the deflexion of the electrometer-needle immediately began to decrease; the rate at which it decreased was determined by measuring the diminution of the deflexion in 30 seconds.

Let D be the original deflexion of the electrometer, let this correspond to a potential-difference equal to αD between the plate and the earth. If l is the distance between the zinc plate and the surface of the water, the potential gradient is $\alpha D/l$. If A is the area of the plate, n the number of ions

per cub. centim., e the charge on an ion, u_0 the velocity of the ion under unit potential gradient, then the quantity of negative electricity lost by the plate in one second is

$$A n e u_0 \alpha D / b.$$

But the plate is observed to fall in potential by αd per second, and the capacity of the system attached to the plate is C; hence the loss of electricity by the plate per second is

$$C \alpha d.$$

Equating these two expressions for the loss of electricity, we get

$$A n e u_0 \alpha D / b = C \alpha d$$

or

$$e = \frac{b \quad C d}{n u_0 \, A \, D}.$$

Hence knowing b, C, A, and u_0, if we measure n and d/D we can determine e.

To calculate n we begin by finding the volume of water deposited in consequence of the expansion in each cub. centim. of the expansion. In my previous paper I show how this can be determined if we know the ratio of the final to the initial volumes and the temperature before expansion. In the present experiments the final volume was 1·36 times the initial volume, and the temperature before expansion was 18°·5 C. It follows from this that 50×10^{-7} cub. centim. of water were deposited in each cub. centim. of the expansion chamber.

If a is the radius of one of the drops, the volume of a drop is $4\pi a^3/3$, and hence $n' = \dfrac{3 \times 50 \times 10^{-7}}{4\pi a^3}$; here n' is the number of ions per cub. centim. of the expanded gas.

If v is the velocity of fall

$$v = \frac{2}{9} \frac{g a^2}{\mu}.$$

Since for air $\mu = 1{\cdot}8 \times 10^{-4}$, we find

$$a = \frac{v^{\frac{1}{2}}}{1{\cdot}1 \times 10^3}$$

and

$$\frac{4}{3} \pi a^3 = 3{\cdot}14 \, v^{\frac{3}{2}} \times 10^{-9}$$

$$n' = \frac{5000}{3{\cdot}14 \, v^{\frac{3}{2}}}.$$

This is the number in 1 cub. centim. of the expanded gas; the number in 1 cub. centim. of the gas before expansion is $1 \cdot 36\, n'$. To find n the number of ions we must subtract from $1 \cdot 36\, n'$ the number of drops which are formed when the ultra-violet light does not fall on the plate. With an expansion as large as 1·36, Mr. Wilson has shown that a few drops are always formed in dust-free air, even when free from the influence of Röntgen rays or ultra-violet light. If V be the velocity with which these drops formed in the absence of the light fall, then the number of drops due to these nuclei is

$$\frac{1 \cdot 36 \times 5000}{3 \cdot 14\, \mathrm{V}t}.$$

Subtracting this from $1 \cdot 36\, n'$, we find

$$n = 2 \cdot 07 \times 10^{3} \left\{ \frac{1}{vt} - \frac{1}{\mathrm{V}t} \right\}.$$

In making this correction we have assumed that the clouds form round these nuclei even when the negative ions due to the ultra-violet light are present. If the cloud formed more readily about the negative ions than about the nuclei, the ions would rob the nuclei of their water, and we should not need the correction. The following table gives the result of some experiments; in making the observation on the cloud the same potential-difference between the plate and the water was used as when observing the value of d/D: u_0 was determined by Prof. Rutherford as $1 \cdot 5 \times 3 \times 10^{2}$, and A was $\pi(1 \cdot 6)^2$ throughout the experiments.

b.	C.	d/D.	v.	V.	$e \times 10^{10}$
1·2	62	·0017	·13	·3	7·9
1·2	62	·0019	·11	·3	7·3
·9	50	·0012	·14	·3	5·3
1·2	65	·0035	·08	·3	7·3
1·2	50	·0018	·11	·3	6
1·2	40	·0018	·14	·3	7

The mean value of e is $6 \cdot 8 \times 10^{-10}$. The values differ a good deal, but we could not expect a very close agreement unless we could procure an absolutely constant source of ultra-violet light, as these experiments are very dependent on the constancy of the light; since the electrical part of the experiment measures the average intensity of the light over 30

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seconds, while the observations on the cloud measure the intensity over an interval of a small fraction of a second.

The value of e found by me previously for the ions produced by Röntgen rays was $6{\cdot}5 \times 10^{-10}$; hence we conclude that e for the ions produced by ultra-violet light is the same as e for the ions produced by the Röntgen rays; and as Mr. Townsend has shown that the charge on these latter ions is the same as the charge on an atom of hydrogen in electrolysis, we arrive at the result previously referred to, that the charge on the ion produced by ultra-violet light is the same as that on the hydrogen ion in ordinary electrolysis.

The experiments just described, taken in conjunction with previous ones on the value of m/e for the cathode rays (J. J. Thomson, Phil. Mag. Oct. 1897), show that in gases at low pressures negative electrification, though it may be produced by very different means, is made up of units each having a charge of electricity of a definite size; the magnitude of this negative charge is about 6×10^{-10} electrostatic units, and is equal to the positive charge carried by the hydrogen atom in the electrolysis of solutions.

In gases at low pressures these units of negative electric charge are always associated with carriers of a definite mass. This mass is exceedingly small, being only about $1{\cdot}4 \times 10^{-3}$ of that of the hydrogen ion, the smallest mass hitherto recognized as capable of a separate existence. The production of negative electrification thus involves the splitting up of an atom, as from a collection of atoms something is detached whose mass is less than that of a single atom. We have not yet data for determining whether the mass of the negative atom is entirely due to its charge. If the charge is e, the apparent mass due to the charge supposed to be collected on a sphere of radius a is $\frac{2}{3}e^2/\mu a$; hence m/e in this case is $e/3\mu a$. Substituting the values of m/e and e found above, we find that a would be of the order 10^{-13} centim.

We have no means yet of knowing whether or not the mass of the negative ion is of electrical origin. We could probably get light on this point by comparing the heat produced by the bombardment by these negatively electrified particles of the inside of a vessel composed of a substance transparent to Röntgen rays, with the heat produced when the vessel was opaque to those rays. If the mass was "mechanical," and not electrical, the heat produced should be same in the two cases. If, on the other hand, the mass were electrical, the heat would be less in the first case than in the second, as part of the energy would escape through the walls.

Hitherto we have been considering only negative electrification; as far as our present knowledge extends positive electrification is never associated with masses as small as those which invariably accompany negative electrification in gases at low pressures. From W. Wien's experiments on the ratio of the mass to the electric charge for the carriers of positive electrification in a highly exhausted vacuum-tube (Wied. *Ann.* lxv. p. 440), it would seem that the masses with which positive electrification is associated are comparable with the masses of ordinary atoms. This is also in accordance with the experiments of Elster and Geitel (Wied. *Ann.* xxxviii. p. 27), which show that when positive ions are produced by an incandescent platinum wire in air they are not affected to anything like the same extent as negative ions produced by an incandescent carbon filament in hydrogen.

It is necessary to point out that the preceding statements as to the masses of the ions are only true when the pressure of the gas is very small, so small that we are able to determine the mass of the carriers before they have made many collisions with the surrounding molecules. When the pressure is too high for this to be the case, the electric charge, whether positive or negative, seems to act as a nucleus around which several molecules collect, just as dust collects round an electrified body, so that we get an aggregate formed whose mass is larger than that of a molecule of a gas.

The experiments on the velocities of the ions produced by Röntgen or uranium rays, by ultra-violet light, in flames or in the arc, show that in gases at pressures comparable with the atmospheric pressure, the electric charges are associated with masses which are probably several times the mass of a molecule of the gas, and enormously greater than the mass of a carrier of negative electrification in a gas at a low pressure.

There are some other phenomena which seem to have a very direct bearing on the nature of the process of ionizing a gas. Thus I have shown (Phil. Mag. Dec. 1898) that when a gas is ionized by Röntgen rays, the charges on the ions are the same whatever the nature of the gas: thus we get the same charges on the ions whether we ionize hydrogen or oxygen. This result has been confirmed by J. S. Townsend ("On the Diffusion of Ions," Phil. Trans. 1899), who used an entirely different method. Again, the ionization of a gas by Röntgen rays is in general an additive property; *i. e.*, the ionization of a compound gas AB, where A and B represent the atoms of two elementary gases, is one half the sum of the ionization of A_2 and B_2 by rays of the same intensity, where

A_2 and B_2 represent diatomic molecules of these gases (Proc. Camb. Phil. Soc. vol. x. p. 9). This result makes it probable that the ionization of a gas in these cases results from the splitting up of the atoms of the gas, rather than from a separation of one atom from the other in a molecule of the gas.

These results, taken in conjunction with the measurements of the mass of the negative ion, suggest that the ionization of a gas consists in the detachment from the atom of a negative ion; this negative ion being the same for all gases, while the mass of the ion is only a small fraction of the mass of an atom of hydrogen.

From what we have seen, this negative ion must be a quantity of fundamental importance in any theory of electrical action; indeed, it seems not improbable that it is the fundamental quantity in terms of which all electrical processes can be expressed. For, as we have seen, its mass and its charge are invariable, independent both of the processes by which the electrification is produced and of the gas from which the ions are set free. It thus possesses the characteristics of being a fundamental conception in electricity; and it seems desirable to adopt some view of electrical action which brings this conception into prominence. These considerations have led me to take as a working hypothesis the following method of regarding the electrification of a gas, or indeed of matter in any state.

I regard the atom as containing a large number of smaller bodies which I will call corpuscles; these corpuscles are equal to each other; the mass of a corpuscle is the mass of the negative ion in a gas at low pressure, i. e. about 3×10^{-26} of a gramme. In the normal atom, this assemblage of corpuscles forms a system which is electrically neutral. Though the individual corpuscles behave like negative ions, yet when they are assembled in a neutral atom the negative effect is balanced by something which causes the space through which the corpuscles are spread to act as if it had a charge of positive electricity equal in amount to the sum of the negative charges on the corpuscles. Electrification of a gas I regard as due to the splitting up of some of the atoms of the gas, resulting in the detachment of a corpuscle from some of the atoms. The detached corpuscles behave like negative ions, each carrying a constant negative charge, which we shall call for brevity the unit charge; while the part of the atom left behind behaves like a positive ion with the unit positive charge and a mass large compared with that of the negative ion. On this view, electrification essentially involves the splitting up of the atom, a part of the mass of the atom getting free and becoming detached from the original atom.

A positively electrified atom is an atom which has lost some of its "free mass," and this free mass is to be found along with the corresponding negative charge. Changes in the electrical charge on an atom are due to corpuscles moving from the atom when the positive charge is increased, or to corpuscles moving up to it when the negative charge is increased. Thus when anions and cations are liberated against the electrodes in the electrolysis of solutions, the ion with the positive charge is neutralized by a corpuscle moving from the electrode to the ion, while the ion with the negative charge is neutralized by a corpuscle passing from the ion to the electrode. The corpuscles are the vehicles by which electricity is carried from one atom to another.

We are thus led to the conclusion that the mass of an atom is not invariable: that, for example, if in the molecule of HCl the hydrogen atom has the positive and the chlorine atom the negative charge, then the mass of the hydrogen atom is less than half the mass of the hydrogen molecule H_2; while, on the other hand, the mass of the chlorine atom in the molecule of HCl is greater than half the mass of the chlorine molecule Cl_2.

The amount by which the mass of an atom may vary is proportional to the charge of electricity it can receive; and as we have no evidence that an atom can receive a greater charge than that of its ion in the electrolysis of solutions, and as this charge is equal to the valency of the ion multiplied by the charge on the hydrogen atom, we conclude that the variability of the mass of an atom which can be produced by known processes is proportional to the valency of the atom, and our determination of the mass of the corpuscle shows that this variability is only a small fraction of the mass of the original atom.

In the case of the ionization of a gas by Röntgen or uranium rays, the evidence seems to be in favour of the view that not more than one corpuscle can be detached from any one atom. For if more than one were detached, the remaining part of the atom would have a positive charge greater than the negative charge carried by each of the detached corpuscles. Now the ions, in virtue of their charges, act as nuclei around which drops of water condense when moist dust-free gas is suddenly expanded. If the positive charge were greater than the individual negative ones, the positive ions would be more efficient in producing cloudy condensation than the negative one, and would give a cloud with smaller expansion. As a matter of fact, however, the reverse is the case, as C. T. R. Wilson (Phil. Trans. 1899) has shown that it requires a considerably greater expansion to produce a

RÉPUBLIQUE FRANÇAISE.

MINISTÈRE DU COMMERCE ET DE L'INDUSTRIE.

DIRECTION DE LA PROPRIÉTÉ INDUSTRIELLE.

Copie officielle d'un brevet d'invention délivré sous le n° 328.687

MÉMOIRE DESCRIPTIF annexé au brevet d'invention de Quinze ans pris le 21 Janvier 1903 par Monsieur Gillet de Valbreuze (Robert) représenté par Monsieur Armengaud Aîné, 21 Bd Poissonnière à Paris

et qui a été délivré par arrêté du Ministre du Commerce, de l'Industrie, des Postes et des Télégraphes en date du 2 Mai 1903, pour Perfts au mode de transmission par ondes électriques connu sous le nom générique de télégraphie sans fil

RÉPUBLIQUE FRANÇAISE. 3541

OFFICE NATIONAL DE LA PROPRIÉTÉ INDUSTRIELLE.

BREVET D'INVENTION

du 21 janvier 1903.

XII. — Instruments de précision. **N° 328.687**

4. — Télégraphie, téléphonie.

Brevet de quinze ans demandé le 21 janvier 1903 par **M. Robert GILLET de VALBREUZE** (France).

Perfectionnements au mode de transmission par ondes électriques connu sous le nom générique de télégraphie sans fil.

Délivré le 7 mai 1903; publié le 18 juillet 1903.

Cette invention se rapporte à des perfectionnements au mode de transmission par ondes électriques connu sous le nom générique de télégraphie sans fil.

Il est nécessaire, pour bien comprendre le but de cette invention, de rappeler le principe des appareils actuels et les raisons pour lesquelles leur emploi ne permet pas d'obtenir la syntonisation. On emploie actuellement comme transmetteurs des excitateurs montés en dérivation sur le secondaire d'une bobine d'induction dont les extrémités sont reliées d'une part à la terre et d'autre part à l'antenne, soit directement soit par l'intermédiaire d'un transformateur. Pour les récepteurs on utilise les propriétés de certains contacts imparfaits dont la résistance électrique s'abaisse considérablement lors du passage d'une onde électromagnétique.

La sécurité des communications exige que les signaux émis par un transmetteur donné ne soient décelés que par un récepteur déterminé et que les signaux décelés par ce récepteur ne proviennent que du transmetteur donné. Pour obtenir cette syntonisation, il est absolument nécessaire d'accorder les mouvements vibratoires transmis avec les oscillations que le circuit récepteur serait capable d'émettre s'il était employé comme transmetteur; quand ces conditions sont remplies, c'est-à-dire quand la fréquence propre du récepteur est accordée avec la fréquence du transmetteur, il y a résonance entre les deux appareils, exactement comme entre deux diapasons accordés.

Les divers procédés de syntonisation imaginés jusqu'ici n'ont donné aucun résultat véritablement sélectif : la raison doit en être cherchée dans ce que l'on emploie comme transmetteur un excitateur. En effet, dans l'excitateur, l'étincelle remplit le rôle d'un déclenchement brutal entre deux charges contraires d'électricité et donne lieu dans le circuit transmetteur à des oscillations amorties dont l'amplitude et la période décroissent rapidement; en outre, les variations continuelles de la résistance, dues aux variations de l'étincelle oscillante, changent à chaque instant la nature des oscillations; la perturbation d'un excitateur est donc complexe et résulte de la superposition de nombreuses vibrations dissemblables. Or pour obtenir la syntonisation, il faut avoir recours aux phénomènes dits de résonance, et pour pouvoir faire de la résonance il faut qu'un régime permanent ait pu s'établir.

Le problème est donc insoluble avec les appareils actuels. Le système objet de cette invention permet d'obtenir la syntonisation avec des appareils reposant sur l'emploi de tubes à vide.

RÉSUMÉ.

Les points caractéristiques de cette invention sont :

Dans les systèmes de transmission à distance par ondes électriques, connus sous le nom générique de télégraphie sans fil :

1° L'emploi d'un tube à vide accompagné d'un condensateur pour produire, avec l'énergie fournie par une source d'électricité, des courants alternatifs de fréquence très rapide et bien déterminée ;

2° Emploi d'un organe dit soupape électrique, constitué par un tube à vide, ou de plusieurs soupapes semblables combinées entre elles, pour transformer en courants toujours de même sens les courants alternatifs de fréquence très rapide transmis aux appareils récepteurs.

Par procuration de M. Gillet de Valbreuze :

ARMENGAUD aîné.

N° 328.687 M. Gillet de Valbreuze Pl. unique

Fig. 1

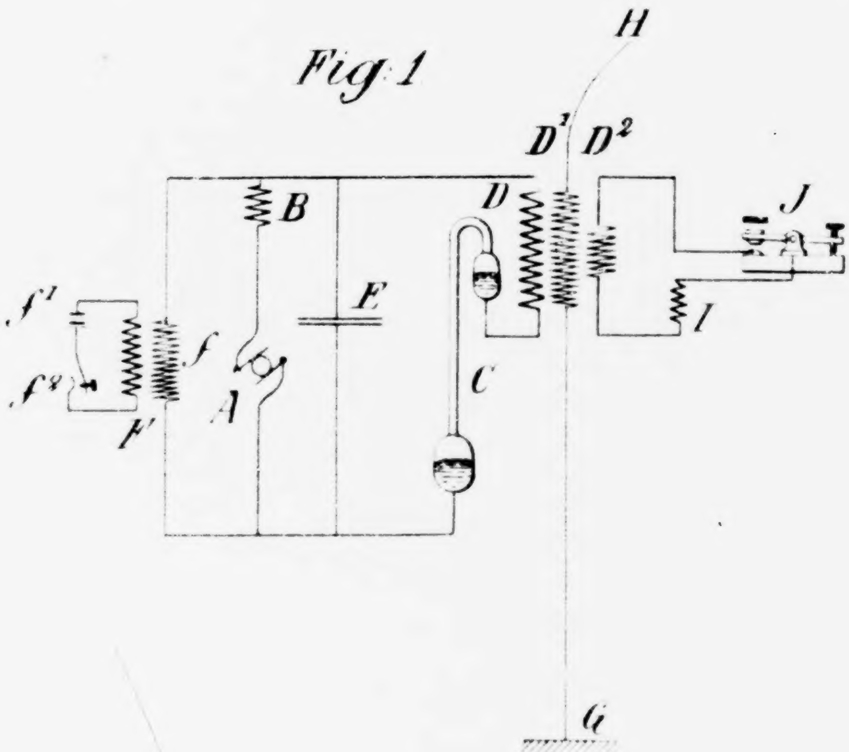
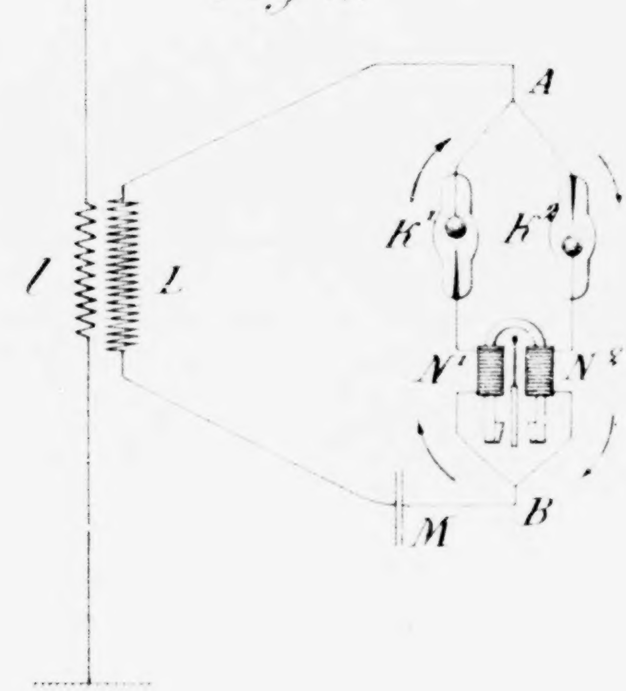


Fig. 2



Le Directeur de la Propriété Industrielle soussigné, certifie que les dates de dépôt de délivrance et de publication portées sur la copie imprimée du brevet ci-joint, N° 328.687. pris le 27 Janvier 1903, sont bien les dates réelles de dépôt de délivrance et de publication dudit brevet.

pour Le Directeur
de la Propriété Industrielle

Le Chef de Bureau

JUILLET 1944

Collationné
Une demi-rôle manuscrit
Deux rôles et demi imprimés
Une planche annexée.

Paris, le 8 MAI 1923
Pour expédition certifiée conforme

LE CHEF DE BUREAU

[fol. 3106] DEFENDANT'S EXHIBIT B-2

French Republic.

Minister of Commerce and Industry

Bureau of Industrial Property

Official Copy of a Patent of Invention Delivered under the No. 328,687

Specification Annexed to the patent of invention of August 15 taken the 27th of January, 1903 by Mr. Gillet of Valbreuze (Robert) represented by Mr. Armengaud, Jr., 21 Boulevard Poissonniere of Paris and which has been delivered by decree of the Minister of Commerce and Industry of Posts and Telegraphs under date of May 7, 1903 for improvements in the mode of transmission by electric waves known under the generic name of wireless telegraphy.

[fol. 3107] French Republic

National Bureau of Industrial Property

Patent of Invention of Jan. 21, 1903

XII Instruments of Precision 4 Telegraphy & Telephony

328,687

Patent for fifteen years, filed January 21, 1903, by Mr. Robert Gillet de Balbreuze (France).

Improvements in the method of transmission by electric waves known under the generic name of telegraphy without wires.

Delivered May 7, 1903; published July 18, 1903.

This invention relates to improvements in the method of transmission by electric waves known under the generic name of wireless telegraphy.

It is necessary in order to well understand the object of this invention to recall the principle of the present apparatuses and the reasons why their use does not permit of obtaining syntonism. There are at present employed as transmitters, exciters mounted in shunt on the secondary

of an induction coil, the extremities of which are connected on the one hand to the earth and on the other hand to the antenna, either directly or by means of a transformer. For the receivers there are utilized the properties of certain imperfect contacts, the electrical resistance of which is considerably lowered on the passage of an electromatic wave.

Safety of communication demands that the signals emitted by a given transformer be disclosed only by a pre-determined receiver, and that the signal disclosed by this receiver should come only from the respective transmitter. In order to obtain this syntonism, it is absolutely necessary to tune the vibratory movements transmitted with the oscillations which the receiving circuit would be capable of emitting, if it should be employed as a transmitter; when these conditions are fulfilled, that is to say, when the natural frequency of the receiver is tuned to the frequency of the transmitter, there is *resonance* between the two apparatuses, exactly as between two tuned tuning forks.

The various processes of syntonization devised up to the present time have given no truly selective result; the reason therefore is to be sought in the fact that an excit*ed* is employed as a transmitter. In fact, in the excit*ed* the spark fulfills the role of a rough release between two opposite charges of electricity, and gives rise in the transmitting circuit to damped oscillations, the amplitude and period of which decrease rapidly; moreover, the continual variations of the resistance, due to the variations of the oscillating spark, change the nature of the oscillation at every instant. [fol. 3108] The disturbance of an excit*ed* is then complex, and follows from the superposition of numerous dis-similar vibrations. Now, in order to obtain syntonization, it is necessary to have recourse to phenomena called resonance, and to be able to produce resonance, it is necessary that a permanent regime may be able to be established.

The problem is then unsolvable with the present apparatus. The system forming the subject matter of this invention allows of obtaining syntonism with apparatus based upon the use of vacuum tubes.

In 1875 Mr. W. de LaRue, having subjected a vacuum tube to the action of a battery of 1080 elements, proved that the continuous, luminous vien was stratified as soon as there was interposed a condenser in parallel, and he shows that the circuit was then traversed by an alternating current of a very high frequency and very definite.

Recently Mr. Hewitt has brought to incandescence by the effect of a continuous current of 110 volts, a vacuum tube with mercury electrodes (Cooper Hewitt lamp). This tube requires a preliminary excitation obtained by means of a Ruhmkorff coil, or a coil of self-inductance.

Mounting a condenser in parallel with a Hewitt tube fed by a continuous current, there is obtained in the circuit an alternating current of very high and well determined frequency, as in the experiment of W. de LaRue. It is probable that by the aid of this same apparatus, suitably modified, we could succeed also in transforming industrial alternating current of low frequency into a current of high frequency.

The system forming the subject matter of this invention consists essentially in using as a transmitter, in transmissions to a distance, known commonly under the name of wireless telegraphy, a vacuum tube of the class mentioned above, accompanied by a condenser for the purpose of obtaining alternating currents of high frequencies suitable for the transmissions.

Fig. 1 of the annexed drawing represents diagrammatically an installation, according to this system, of transmitter for Morse signals.

A circuit comprises any source whatever A of continuous current of above 100 volts, and of a choking coil B, the vacuum tube C on primary D of a transformed without iron core. A condenser E and secondary f of a small Ruhmkorff coil F, serving for the excitation are mounted in parallel with this circuit. f^1 indicates the battery feeding this coil and f^2 the switch by which it is momentarily placed in circuit.

The transformer comprises two secondary coils D^1 and D^2, the extremities of one of them, D^1, are connected to earth, G, and to the transmitting antenna H, the extremities of the other, D^2, are connected to a damping circuit, I, comprising a not very large self-induction and a Morse key, J, serving for the transmission. The object of this arrangement is to not cool off the tube in the intervals of the dashes or dots representing the alphabet, as would [fols. 3109-3110] happen if the interruptor were cranched on the principal circuit. With this transmitted the antenna is the seat of induced currents of a constant amplitude, and of a high and well-determined frequency. Their period $t^1 = 2.$ LC should be rendered equal to the natural period of the

receiver $t^1 = 2.\ L^1C^1$ in order to have perfect resonance: for that LC^1 will be made equal to L^1C^1 by varying L by means of an additional self-induction coil, of a variable number of windings.

As receiver there is employed an apparatus which allows of re-transforming the alternating current into a continuous current, actuating a relay. For that recourse is had to apparatus called electric valves, placed as described hereinafter, and diagrammatically represented by Fig. 2. Two tubes K^1 and K^2 are taken, having for electrodes a point and ball very close together. The degree of vacuum is determined by the blue tint of the luminosity due to the passage of a current. It is probable that with tubes containing an electrode of mercury and an electrode of iron or of nickel, we should obtain similar valves applicable to strong currents). These tubes are mounted in multiple, the electrodes being opposite each other, and interposed in a circuit containing the secondary L of a transformer without iron core and a condenser M; the primary 1 of the transformer is in series with the antenna and the earth. Each of these two coils N^1 and N^2 of a polarized relay extremely sensitive, is mounted in series with one of the tubes. When an alternating current of high frequency is received by the antenna, it induces in the circuit a periodic current, the positive portions of which pass through one of the tubes, while the negative portions pass through *through* the other. The circuit A, K^1, N^1, B, N^2, K^2, A is then traversed by currents always of the same direction actuating the relay N^1, N^2; the self-induction of these two coils controls the redressed currents, and there is produced a current practically continuous.

Resume.

The characteristic points of this invention are:

In systems of transmitting to a distance by means of electric waves known under the generic name of wireless telegraphy.

1. The use of a vacuum tube accompanied by a condenser in order to produce, with the energy furnished by a source of electricity, alternating current of a very rapid and well determined frequency.

2. The use of a device called an electric valve formed by a vacuum tube, or of several similar valves combined together in order to transform into currents always in the

same direction, the alternating currents of very rapid frequency transmitted to the receiving apparatus.

By power of attorney, by Robert Gillet de Valbreuze.

[fol. 3111] DEFENDANT'S EXHIBIT C-2

The Thermionic Valve and its Developments in Radio Telegraphy and Telephony, by J. A. Fleming, 1919

Chapter III.—The Three-Electrode Valve

1. An improvement on the hot and single cold electrode oscillation valve described in the previous chapter was effected by the introduction of a second cold electrode in the form of a grid, wire zig-zag or perforated plate placed in between the hot cathode and cold electrode of the Fleming valve.

This modification enabled the appliance to be used not merely to rectify electric oscillations, but to relay or repeat them on a magnified scale, so that when employed with a telephone, as below described, a considerable increase in oscillation-detecting power ensued. Also it made it possible to use the instrument as a telegraphic relay of a certain kind. The credit for this structural improvement must be given to Dr. Lee de Forest, who arrived at it by a series of steps presently to be mentioned.

Underrating, however, the author's previous work in the invention of the two-electrode valve, he took the view that his improvement constituted a new invention originating entirely with himself, independent of everything that had been done before, and radically different in operation from the Fleming valve.

Hence he availed himself of many opportunities for disparaging the author's prior work, incorrectly, representing the two-electrode oscillation valve as a comparatively useless laboratory device appropriated from Mr. Edison, or else "taken from the early German scientists by Professor Fleming."[1]

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[1] See letter of L. de Forest in *The Electrician*, vol. lxi., p. 804, September 4th, 1908. A prolonged controversy took place on this subject. See de Forest's letters in *The Electrician*, vol. lviii., p. 425, December 28th, 1906; vol. lxi.,

The judgment of Judge Mayer and the confirmatory unanimous judgment of the Court of Appeals in the action-at-law already mentioned in Chapter II have cleared away these misconceptions and shown that his improvements are of the nature of modifications of the original invention of the oscillation valve, but involve the same physical prin-
[fol. 3112] ciples, and cannot be exercised in the United States of America in commercial manufacture without infringing certain claims in the author's fundamental valve patent as long as it remains in force.

The stages by which de Forest reached this modification or improvement, were as follows: In or before 1904 he was engaged in researches on the production of some new detector devices he called "oscillation responsive devices," in which two electrodes were immersed in the flame of a Bunsen burner and connected respectively to the earth and to a receiving aerial. They were also joined by a circuit containing a battery and a telephone. The idea seems to have been that the oscillations in the aerial would put the "gaseous medium"—*i.e.*, the flame, "into a condition of molecular activity," and that it would then become a conductor and pass the current from the battery through the telephone in series with it and thus produce a sound.

He applied, on February 2nd, 1905, for a United States patent for these devices, the specification having been actually signed by him on November 4th, 1904, a few days before the application of the author for the British valve patent, No. 24,850, of 1904, and some weeks before the application for the corresponding United States patent, No. 803,684.

In this specification, No. 979,275, of 1905, Lee de Forest included amongst his Bunsen burner oscillation responsive devices one consisting of a bulb filled with air or gas, in which were two electrodes intended to be heated by a dynamo, but as the electrodes are shown in the diagram connected by a telephone, it is not at all clear how they could carry a heating current from the dynamo (see p. 106, Fig. 56*a*).

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p. 804, September 4th, 1908; vol. lxi., p. 1006, October 9th, 1908; and vol. lxxii., p. 659, January 23rd, 1914. Also the author's replies in *The Electrician*, vol. lviii, p. 263, November 30th, 1906; vol. lviii., p. 464, January 4th, 1907; vol. lxi., p. 843, September 11th, 1908; vol. lxxii., p. 377, December 5th, 1913; vol. lxxii., p. 660, January 23rd, 1914.

The specification contains forty-one claims and abounds in such vague phrases as "a sensitive constantly receptive oscillation responsive device comprising in its construction a sensitive conducting gaseous medium." The various items in this United States patent of de Forest, No. 979,275, were subsequently divided into separate applications and formed the subject-matter of three subsidiary specifications—viz., No. 867,876, application of April 4th, 1906; No. 867,877, application of June 12th, 1907; No. 867,878, application of June 12th, 1907.

It is not at all certain that any of these devices were ever put into practical operation, but, nevertheless, their patentee referred to this United States patent, No. 979,275, some ten years afterwards as his "basic American patent."[2]

When, however, in 1916, the question of its real value came to be discussed impartially in a Court of Law, Judge Mayer, who tried the case, in giving judgment on September 20th, 1916, in the action brought by the Marconi Wireless Telegraph Company of America against de Forest Radio Telephone and Telegraph Company, after a prolonged legal contest on the Fleming and de Forest patents, said: "This burner detector of de Forest has never been commercially used and thus has not made any impression on the art. A mere inspection of the device in operation will show that [fol. 3113] this flickering flame is impracticable. The most that can be said for it is that it may contain the germ of an idea which in this rapidly progressing art may hereafter be utilised in some way. Whilst, therefore, it is not necessary to declare this patent and its three subsidiaries invalid, it may be eliminated from this case for all practical purposes."

Soon after the date of application for the Bunsen burner patent de Forest had brought to his notice the paper published by the author in the *Proceedings of the Royal Society of London* issue of March 16th, 1905, which had been read to the Society on February 9th of that year entitled, "On the Conversion of Electric Oscillations into Continuous Currents by means of a Vacuum Valve."

It is clear from subsequent events that this paper was the means of starting trains of though in his mind which had certainly not been there before its perusal. He must then

[2] See a letter by Dr. Lee de Forest to *The Electrician* (London), on January 23rd, 1914, vol. lxxii., p. 659; and reply by J. A. Fleming, *ibid.*, p. 660.

have become strongly impressed with the idea that what was required was not "a gaseous medium in a state of molecular activity," but some means of rectifying, as the author had shown, the trains of electric oscillations into unidirectional currents to make them affect a telephone or other instrument. Accordingly, in his next U. S. patent application, No. 823,402, filed December 9th, 1905, covering inventions in radiotelegraphy, we find he made use of the Fleming valve, and gave also a reference to its published description in the *Proceedings of the Royal Society*, March 16th, 1905.

Very ingeniously, however, he couples with this valve, and as equivalent to it, one of his Bunsen burner detectors, the flame of which is rendered more conducting by sodium or other salts, and this flame is now described as having a non-symmetrical conductivity. He states that positive electricity passes more readily in one direction in the flame than in the opposite.

The Bunsen burner had thus been transmitted into a rectifier of oscillations, and is described as a "valve" in this de Forest specification. His next step was to apply, on January 18th, 1906, for a United States patent, No. 824,637, for an oscillation-responsive device "of great simplicity and sensitiveness." In this specification great cleverness is shown in the treatment by which the oscillation responsive device, shown in his Bunsen burner patent, No. 979,275 (Fig. 6) and its subsidiary or divided application, No. 867,876, of April 4th, 1906, is gradually transformed into an identity with the author's oscillation valve, but disguised by the use of pseudo-scientific language, so as to appear to be something quite novel.

The glass bulb is described as a "receptacle," and the more or less perfect vacuum is a "gaseous medium, which is to be put into a condition of "molecular activity," "highly sensitive to electrical oscillations," when an electric current is employed "to heat two highly-resistant electrodes."

Diagrams are then given in this specification in which there is, as it were, a slow evolutionary transformation from the sterile oscillation responsive device of specification No. 979,275 (Fig. 6) to a nearly complete identity with the [fol. 3114] author's previously described valve detector. The diagrams *a, b, c, d*, in Fig. 56 are taken from de Forest's U. S. specifications, and show how ingeniously this metamorphosis was managed. The series, in fact, reminds us forcibly of the illustrations in books on geology, showing the gradual

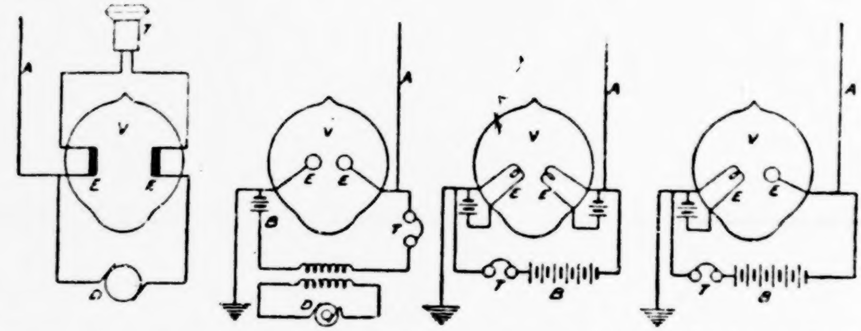

FIG. 56 (A). Fig. 6, U.S. Patent, No. 979,275, Nov 4th, 1904

FIG. 56 (b). Fig. 5, U.S. Patent, No. 824,637, Jan. 18th, 1906.

FIG. 56 (c). Fig. 1, U.S. Patent, No. 824,637, Jan. 18th, 1906

FIG. 56 (d). Fig. 3, U.S. Patent, No. 824,637, Jan. 18th, 1906.

FIG. 56. Diagrams taken from U.S. Patent Specifications of Lee de Forest.

evolution of present-day forms of animal life from ancient prehistoric types now extinct.

In the above specification it was stated that heating the electrodes is not even necessary, and that the gas may be "rendered sensitive to electrical oscillations by heating or by any other suitable means." As an example of such "suitable means" it is sufficient to cover the electrodes with "some radio-active substance such as radium bromid."

The next step was to sub-divide this broad specification into others covering its separate parts—viz., No. 836,070 (application of May 19th, 1906), and No. 836,071 (application of May 19th 1906). The first of these includes and describes identically the same article as a Fleming valve. The "receptacle" is now "partially exhausted." Two electrodes are sealed into it. One electrode, *E*, may be an "ordinary incandescent lamp carbon filament," the other "a disk of platinum or other material." The "gaseous medium" between them is rendered sensitive to electrical oscillations by the radiation of heat from the electrode, *E*, the said electrode being heated by a source of energy.

Influenced by this verbal camouflage, the United States Patent Office examiners could hardly help believing that the above specification described something entirely new and different from the simple Fleming valve for which a United States patent had been applied and issued months before, the only difference being that in the former specification the valve is shown associated with a telephone and

boosting battery as signal detector, and in the latter with a galvanometer or other current-detecting instrument.

In order to maintain the tradition that the Bunsen burner detector was the real parent of all subsequent forms of valve, Dr. Lee de Forest continued his course on January 20th, 1906, by filing an application, No. 824,638, for another Bunsen burner patent. In this case electrodes are placed in a Bunsen flame. "These may consist of platinum or carbon, or may be of platinum and the other of carbon." "When [fol. 3115] electrical oscillations are developed in the antenna by electromagnetic signal waves the passage of such oscillations through the sensitive gaseous conducting medium between the electrodes alters the conductivity thereof and thereby alters what may be termed the internal resistance of the flame battery constituted by the electrodes and the flame." There is no proof that any "sensitive gaseous medium" ever acted in this manner or that a single wireless message was ever received by this suggested form of "oscillation responsive device."

In his next patent application the pendulum swings back again in the direction of the Fleming valve, and on February 14th, 1906, we find de Forest making another patent application, No. 837,901, in which he again declares he has "discovered that if a gaseous medium intervening between two separated electrodes be put into a condition of molecular activity by heating the same or otherwise putting it into a condition of molecular activity, said medium becomes highly sensitive to electrical oscillations." The actual instrument figured in the diagrams of this specification is, however, an incandescent electric lamp arranged as an oscillation valve having a projection on the bulb filled with mercury which acts as the cold electrode. An electromagnet is shown in the diagram placed near the bulb, which is said "will greatly increase the sensitiveness of the detector."

This application was followed by another on August 27th, 1906, No. 841,386, in which an oscillation detector is described which is said to have many uses. It comprises now "an evacuated vessel of glass or other suitable material, having two separated electrodes, between which intervenes the gaseous medium which when sufficiently heated or otherwise made highly conducting forms the sensitive element of my oscillation detector." One of these electrodes is to be a carbon or tantalum filament and the other a cold metal

plate or pair of plates. In the diagrams the filament is shown connected to a battery through a rheostat and outside the lamp the plates are connected with the lamp filament terminals through a telephone and a boosting battery. In some cases magnets are to be placed outside the bulb or coils of wire surrounding it.

In order carefully to distinguish this oscillation-responsive device from the Fleming valve, to which it had unfortunately so strong a resemblance, a new name for it was coined. It was called an *audion*. The patentee says this name is to include other devices of his invention "employing a conducting gaseous medium as the sensitive element."

It is curious how de Forest returns again and again in his specification to such meaningless expressions as the above.

2. Having secured, as he no doubt thought, a sound position — regard to patent priority, Dr. Lee de Forest next read a paper to the *in* American Institute of Electrical Engineers, New York, in October, 1906 (see *Transactions, American Institute of Electrical Engineers*, vol. xxv., p. 735, 1906), entitled "The Audion: A New Receiver for Wireless Telegraphy." The paper was discursive and also remarkable for the absense of any correct and proper history of the subject.

[fol. 3116] The author of it began by giving an account of his Bunsen burner experiments as the foundation of all his work and he then gives a single reference to a paper by Elster and Geitel, published in *Wiedemann's Annalen*, vol. xvi., 1882, and he also gives a diagram taken from one of their subsequent papers. The paper of Elster and Geitel which he quotes—viz., *Wied. Ann.*, vol. xvi., 1882—contains no reference to the diagram he gives of the apparatus, consisting of a glass bulb having a wire stretched across it, intended to be heated by an electric current, and an insulated metal plate placed near it and carried on a wire sealed through the glass (see Fig. 19 of Chap. I. of this book). The title of Elster and Geitel's 1882 paper is "On the Electricity of Flames," and no apparatus is described in this paper such as that de Forest depicts. This bulb was not used by Elster and Geitel until five years later and is described by them in a paper entitled "On the Ionisation of Gases by Incandescent Bodies," printed in *Wiedemann's Annalen* for 1887, vol. xxxi., p. 109.

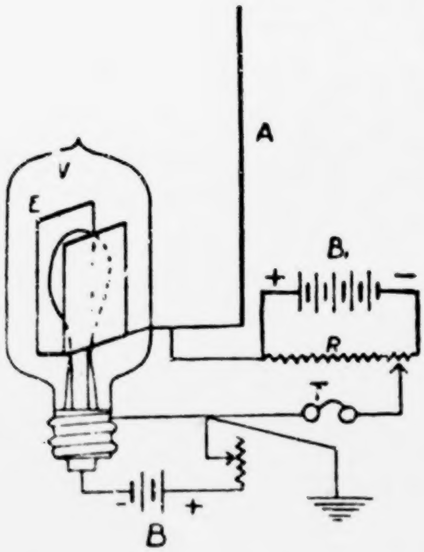

Fig. 57. Lee de Forest's Two-Electrode Audion of 1906

Moreover in this 1887 paper, Elster and Geitel only used a *platinum* wire across the bulb, and it was not until two years later, in 1889 (see *Wied. Annalen*, vol. xxxvii., p. 319, 1889), that they experimented with a carbon filament and found that it gave off negative electricity when incandescent.

It was in December, 1889, that the author sent to the Royal Society of London a paper dealing with the "Edison effect" in carbon glow lamps and in the electric arc and the transference of negative electricity from hot to cold electrodes in vacuum bulbs. There is not the slightest reference to this work in de Forest's paper.

This point is important, as it shows clearly the want of care and fairness in collecting information and verifying references. Moreover, de Forest refers to the author's prior work in connection with the use of a glow lamp having a plate sealed into the bulb for rectifying high-frequency currents as experiments with an "Elster and Geitel tube" (see below). He then went on to describe as a new invention of his own a detector for wireless telegraphy consisting of a glass bulb evacuated of its air having in it a horseshoe shaped filament of carbon or tantalum carried on wires sealed through the glass and rendered incandescent by the current from a battery. On either side of the filament were fixed two metal plates he calls "wings" carried on a platinum wire sealed through the glass. Outside the lamp the two plates were connected with the positive terminal of the filament through a circuit containing a [fol. 3117] galvanometer, a telephone, and a battery of cells having its positive terminal joined to the wings (see Fig. 57).

He omitted to mention that this arrangement had already been patented by the author in Great Britain as a radiotelegraphic detector. He also gave other diagrams of

audions with coils of wire round the lamp bulb, the diagrams being taken from his then recently filed United States Specification, No. 841,386.[3] Judging by the discussion which followed, his explanations of the action of his "audion" were not considered very satisfactory and objections were raised to his newly coined name as a bastard and unsuggestive word.

Broadly speaking, he attributed the operation to the ionisation of the residual gas by the incandescent filament, but he gave no very clear account of the physical processes at work. As regards the line of thought which led him to invent this detector, he stated that it occurred to him that the attenuated and ionised gases around an incandescent filament would undergo very considerable changes when subjected to Hertzian oscillations. He appeared chiefly desirous of proving that his audion was not an oscillation valve but something very superior to it. He strongly insisted that the important novel element was the use of a voltaic battery in series with the telephone supplying a boosting voltage and that this circuit was connected outside the lamp between the "wing" plates and the *positive* terminal of the incandescent filament.

He felt bound, however, to forestall some mention of the Fleming valve patented in Great Britain nearly two years before, and fully described in the author's book, *Principles of Electric Wave Telegraphy*, published nearly six months before the date when he read his paper. Hence he says, *loc. cit.*: "I have arrived as yet at no completely satisfactory theory as to the exact means by which the high frequency oscillations affect so markedly the behaviour of an ionised gas. Fleming points out that when the cold plate of an Elster-Geitel tube is connected to the positive end of the filament and the two put in a high-frequency oscillation circuit, only the positive half of the oscillation can pass from the plate to the filament across the gas. He uses this principle to rectify the Hertzian oscillations, and applies the unidirectional currents of the oscillations themselves to operate a sensitive galvanometer or direct current instrument for quantitative measurements over short

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[3] This patent of de Forest was subsequently held by the United States Circuit Court of Appeals to be void. See Appendix for the full text of this important judgment.

distances. When an independent source of electromotive force is applied in the manner I have described the action becomes quite different. It then operates as a *relay* to the Hertzian energy instead of merely rectifying this energy, so that it can be used directly to give the sense signal."

When, in the discussion, he was asked point blank by Mr. C. B. Ehret to state exactly wherein his audion differed from a Fleming valve, he could only repeat the assertion that his audion was a relay and the valve only a rectifier. He confidently asserted that the Fleming valve was useless in commercial wireless telegraphy.

[fol. 3118] He did not know that at that time the author's valve had been in practical use in radiotelegraphy in Great Britain for nearly eighteen months, and that it had been employed with a telephone, as a receiver, just in accordance with the diagram in his paper.

He was quite wrong in asserting that the form of Fleming valve he called an audion was a relay. Later on he did succeed in devising a form of valve, to be mentioned presently, which does or can act as a relay.

The instrument he described in this 1906 paper was simply a Fleming valve, and it did not operate as a true relay. If Dr. de Forest had studied a little more carefully the Royal Society paper of the author published in March, 1905, he would have seen there a series of characteristic curves delineated for one particular valve, showing the relation of thermionic current to potential difference of the plate and filament. These observations were made by inserting a battery in the external circuit joining the plate and filament, exactly as he did in his experiments, but employing a galvanometer as a current measurer. These curves give a full explanation of the action of the valve when used with such a boosting voltage and a telephone in the valve circuit. They show that for a particular voltage, or P.D., the thermionic current rises with great rapidity, and hence that when that critical steady auxiliary voltage is applied, a small additional voltage, such as is obtained by the superposition of an alternating E.M.F. on the steady E.M.F., may give rise to a large increase in the thermionic current.

Every electrical student was also aware long before 1906 that the telephone is sensitive only to *change of current*, and not to steady or unvarying current. Hence when a telephone is used in place of a galvanometer as a signal recording

instrument it is an advantage to add such a boosting or additional steady E.M.F. in the valve circuit as will bring the effective P.D. between filament and plate to that point on the characteristic curve at which the thermionic current begins to rise rapidly. This, however, is not a true relay action.

Summing up the criticism with regard to this paper of de Forest, we may say that there were three facts which ought in fairness to have been brought to the notice of his audience at the time to enable them to judge of the novelty of this *new* receiver described to them. The first of these was that an exactly similar instrument—viz., an incandescent lamp having a plate or plates sealed into the bulb—had been patented, or patents applied for, as a detector in wireless telegraphy in Great Britain, the United States, German, France, Italy, and other countries by J. A. Fleming and Marconi's Wireless Telegraph Company months before the date when this paper was read by de Forest. Secondly, that it was not new to introduce a boosting or auxiliary voltage into the external or valve circuit; and thirdly, that Senatore Marconi had used such appliances supplied to him by the author of this book eighteen months before October, 1906, with a telephone as a receiver for wireless telegraphy.

There is no intention of suggesting any want of good faith or integrity on the part of Dr. Lee de Forest. He was at that date evidently quite sure that he had full right to [fol. 3119] make use of an incandescent electric lamp having a plate or plates sealed into the bulb as a detector in wireless telegraphy, and he was firmly convinced that his substitution of a battery-boosted telephone in place of a galvanometer was an important invention. Exactly ten years later he had these opinions corrected by the judgment of Judge Mayer, subsequently upheld by the Court of Appeals.

8. Shortly after reading this paper de Forest filed another application on October 25th, 1906, for a United States Patent No. 841,387, entitled "Device for Amplifying Feeble Electrical Currents," and in this we have the first indication of a genuine improvement.

The principal item in this specification is an incandescent lamp having in addition to the carbon or metal loop filament two metal plates sealed into the bulb. This in itself was not novel, because the author had shown in his Royal Society paper of February, 1905, *loc. cit.*, and in the first

edition of his book, *Principles of Electric Wave Telegraphy*, published April, 1906 (see Chapter VI) an oscillation valve with two such cold electrode plates.

Nevertheless, de Forest made a scheme of connections outside the valve as follows:

One of the plates and one terminal (the negative) of the filament in the bulb were connected to the aerial wire and earth of the wireless receiving set, whilst the second plate was connected with the positive terminal of the filament through a telephone and boosting battery. This arrangement was stated to work in virtue of the fact that the electrostatic attraction of the filament and plate connected to the wireless antenna would draw them together and so vary the distance between the filament and the second plate and thus alter the current through the telephone. It may be doubted very much whether any such attractions could be so controlled as to give rise to the required variations in the thermionic current flowing to the second plate to transmit intelligible signals. Moreover, the thermionic current is not sensibly altered by varying slightly the distance between a hot and cold electrode.

This patent specification, however, contained two claims (4 and 6) for a detector device for *amplifying* electric currents. The wording of them was as follows:

Claim 4.—In a device for amplifying electrical currents, an evacuated vessel, three electrodes, sealed within said vessel, means for heating one of said electrodes, a local receiving circuit, including two of said electrodes and means for passing the current to be amplified between one of the electrodes which is included in the receiving circuit and the third electrode.

Claim 6.—In a device for amplifying electrical currents, an evacuated vessel, a heated electrode and two non-heated electrodes sealed within said vessel, the non-heated electrodes being unequally spaced with respect to said heated electrode, a local receiving circuit including said heated electrode and that one of the non-heated electrodes which has the greater separation from the heated electrode and means for passing the current to be amplified between the heated electrode and the other non-heated electrode.

[fol. 3120] As these claims constituted the first mention of what may be called a split cold electrode, the two parts be-

ing differently connected to the hot electrode, and as this formed the basis of a subsequent patent for a three-electrode amplifying valve of true relay action, the Marconi Wireless Telegraph Company of America, who were the plaintiffs in the action against the de Forest Radio Telephone and Telegraph Company in 1916, confessed judgment as to the two above claims, 4 and 6, in U. S. Patent No. 841,387, whilst the defendants withdrew issue on claim 5 of the above patent, which reads as follows:

Claim 5.—In a device for amplifying electrical currents an evacuated vessel enclosing a gaseous medium, means other than the received energy for maintaining said gaseous medium in a condition of molecular activity, means for impressing the current to be amplified upon said gaseous medium and a local receiving circuit having its electrodes within said vessel.

On January 29th, 1907, de Forest filed another application for a United States patent for an improvement in oscillation detectors of the type described in his United States Patents Nos. 824,637 and 836,070. These we have already seen are Fleming valves used with a telephone and boosting battery in series connected to the filament and the collecting plate or cold electrode.

The feature of the new specification, No. 879,532, is the introduction of a second cold electrode in the form of a grid placed between the incandescent filament and the other cold electrode plate. The scheme of connections is shown in Fig. 58.

Dr. de Forest gave no explanation in this specification as to the mode of action of the arrangement, but he states that the effect is to give louder sounds in the telephone used as a signal-receiving instrument. He may have been led to try this type of thermionic detector by his previous experiments, but at any rate the result was to furnish for the first time a modification of the thermionic valve which *can* act as a relay or amplifier under certain conditions.

The corresponding British patent to the above was applied for on January 21st, 1908, and is No. 1,427 of 1908; but under the Patents and Designs Act of 1907 the date claimed for this British patent is January 29th, 1907, being the date of application for the equivalent United States patent. This British patent of de Forest was, however, allowed

to lapse in 1911 and is therefore no longer in force. The name "audion" is now commonly applied in the United States of America to this grid and plate or three-electrode thermionic detector. In Great Britain it is usually called an *amplifying valve*.

Discussions and controversies have taken place over the theory of its physical action, and it was the subject of the above mentioned hotly contested patent action in the United States in 1916 between Marconi's Wireless Telegraph Company of America as plaintiffs, owners of the United States Patent No. 803,684, of April 19th, 1905, issued November [fol. 3121] 7th, 1905, granted to John Ambrose Fleming, of London, England; and de Forest Radio Telephone and Telegraph Company and Lee de Forest, as defendants. The suit was brought for infringement of claims 1 and 37 in the above Fleming patent specification by the defendants.

The defendants made counter-claims on various claims of ten patents by Lee de Forest. At the opening of the trial plaintiffs confessed judgment as to claims 4 and 6 of United States Letters Patent No. 841,387, and defendants withdrew from issue claim 5 of the same patent. Plaintiffs also confessed judgment as to the claims in issue of United States Letters Patent No. 879,532, and defendants withdrew United States Letters Patent No. 837,901.

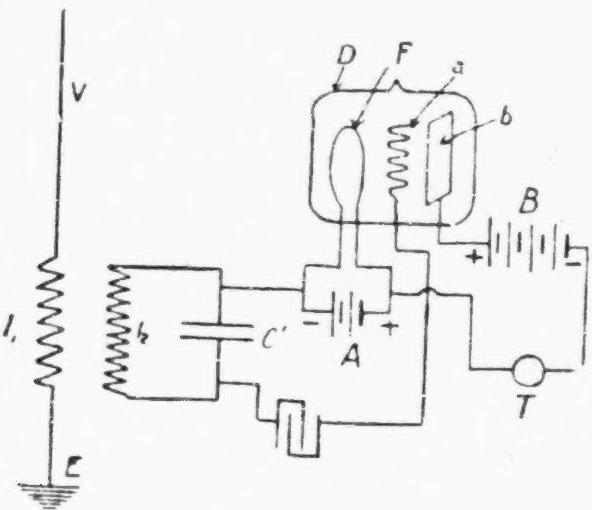

Fig. 58. Lee de Forest's Three-Electrode Audion of 1907. D Glass Bulb. F Filament. a Grid. b Plate. A Filament Battery. B Plate Battery. T Telephone.

Of the counter-claim there remained in issue certain claims of seven patents, viz., Nos. 979,275, 867,876, 867,877,

DEFENDANT'S EXHIBIT E-2

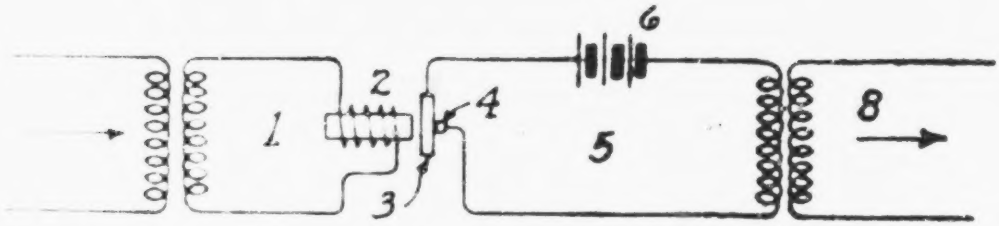

Fig. 1

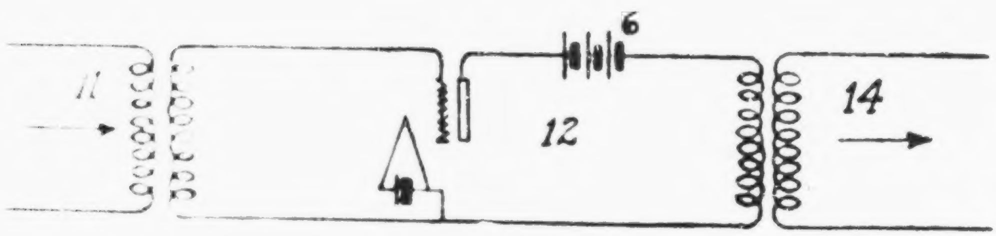

Fig. 2

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DEFENDANT'S EXHIBIT F-2

HERTZ'S RESEARCHES ON ELECTRICAL OSCILLATIONS.

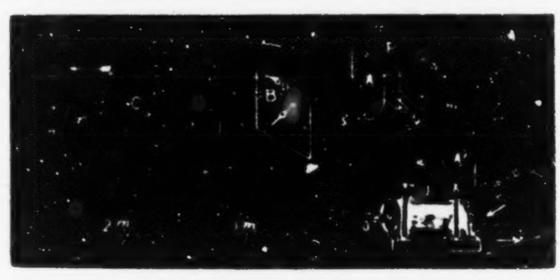

Fig. 11

therefore flow round B towards A′ in the upper portion and away from A′ in the lower portion. The electrostatic and electrodynamic E.M.F.s are therefore in opposite phases and oppose each other's action. If the secondary circuit is rotated through 90deg., through the first principal position, the direct action changes its sign, but not so the action of the waves, so that they now tend to strengthen each other. The same reasoning holds when the air space is at the lowest point of B.

Greater lengths of wire were then included between *m* and *n*, and it was found that the interference became gradually less marked, until with a length of 2·5 metres it disappeared entirely, the sparks being of equal length whether the normal were directed towards or away from P. When the length of wire between *m* and *n* was further increased, the distinction between the different quadrants reappeared, and with a length of 4 metres the disappearance of the sparks was fairly sharp. The disappearance, however, then took place (with the air space at the highest point) when the normal was directed away from P, the opposite direction to that in which the disappearance previously took place. With a still further increase in the length of the wire the interference reappeared and returned to its original direction with a length of 6 metres. These phenomena are clearly to be explained by the retardation of the waves in the wire, and show that here again the direction of motion in the advancing waves changes its sign at intervals of about 2·8 metres.

To obtain interference phenomena with the secondary circuit C in the third principal position the rectilinear wire must be removed from its original position, and placed in the horizontal plane through C either on the side of the plate A or of the plate A′. Practically it is sufficient to stretch the wire loosely and to fix it by means of an insulated clamp on each side of C alternately. It was found that when the wire was on the same side as the plate P the waves in it diminished the previous sparking, and when on the opposite side the sparking was increased, both results being unaffected by the position of the air space in the secondary circuit. Now it has been already pointed out that at the moment when the plate A has its maximum positive charge, and at which, therefore, the primary current begins to flow from A, the current at the first node of the rectilinear wire begins to flow away from the origin. The two currents therefore flow round C in the same direction when C lies between the rectilinear wire and A, and in opposite directions when the wire and A are on the same side of C. The fact that the position of the air space is indifferent confirms the conclusion formerly arrived at, that the direction of oscillation is that due to the electrodynamic E.M.F. These interferences are also changed in direction when the wire *m n* 1 metre in length is replaced by a wire 4 metres in length.

Dr. Hertz also succeeded in obtaining interference phenomena when the centre of the secondary circuit was not in the base line, but these results were of no special importance, except that they confirmed the previous conclusions.

Interference Phenomena at Various Distances.—Interference can be produced with the secondary at greater distances than that of the null point, but care must then be taken that the action of the waves in the wire is of about the same magnitude as the direct action of the primary circuit through the air. This can be effected by increasing the distance between P and A.

Now, if the velocity of propagation of the electrodynamic disturbances through the air is infinite, the interference will change its sign at every half wave length in the wire—that is to say, at intervals of about 2·8 metres. If the velocities of propagation through the air and through the wire are equal, the interference will be in the same direction at all distances. Finally, if the velocity of propagation through the air is finite, but different from the velocity in the wire, the interference will change in sign at intervals greater than 2·8 metres.

The interferences first investigated were those which occurred when the secondary circuit was rotated from the first into the second principal position, the air space being at the highest point. The distance of the secondary from the null point was increased by half metre stages from 0 up to 8 metres, and at each of these positions an observation was made of the effects of directing the normal towards and away from P respectively. The points at which no difference in the sparking was observed in the two positions of the normal are marked 0 in the table below. Those in which the sparking was least, showing the existence of interference, when the normal was directed towards P are marked +, and those in which the sparking was least when the normal was directed away from P are marked –. The experiments were repeated with different lengths of wire *m n*, varying by steps of half a metre from 1 metre up to 6 metres. The first horizontal line in the table gives the distances in metres of the centre of the secondary circuit from the null point, while the first vertical line gives the lengths of the wire *m n*, also in metres.

TABLE I.

	0		1		2		3		4		5		6		7		8
100	+	+	0	–	–	–	–	–	0	0	0	0	0	+	+	+	+
150	+	0	–	–	–	–	0	0	0	0	0		+	+	+	+	0
200	0			–	–	–	0	+	+	+	+	+	0	0	0	0	0
250	0	–	–	–	–	0	0	+	+	+	+	0	0	0	0	0	0
300	–	–	–	–	0	+	+	+	+	+	0	0	0	0		–	–
350	–	–	0	+	+	+	+	+	+	0	0	0	–				–
400	–	–	0	+	+	+	+	0	0	0	0			–	–		–
450	–	0	+	+	+	+	+	0	0	0		–	–			–	0
500		0	+	+	+	+	0	–		–	–	–	0	0	0	0	+
560	0	+	+	+	+	0	0	–	–	–		–	0	0	0	0	
600	+	+	+	+	0	0	–	–			–	0	0		+	+	–

An inspection of this table shows, in the first place, that the changes of sign take place at longer intervals than 2·8 metres; and, in the second place, that the change of phase is more rapid in the neighbourhood of the origin than at a distance from it. As a variation in the velocity of propagation is very unlikely, this is probably due to the fact indicated by theory that the electrostatic E.M.F., which is more powerful than the electrodynamic E.M.F. in the neighbourhood of the primary oscillation, has a greater velocity of propagation than the latter.

In order to obtain a definite proof of the existence of similar phenomena at greater distances Dr. Hertz continued the observations, in the case of three of the lengths *m n*, up to a distance of 12 metres, and the result is given in the table below.

TABLE II.

	0	1	2	3	4	5	6	7	8	9	10	11	12
100	+	0		–	0	0	0	–	–	–	–	–	0
250	0	–		0	+	+	0	0	0	0	–	–	
400	–	0	–	+	0	0	–				0	0	0

If we make the assumption that at the greater distance it is only the E.M.F. of induction which produces any effect, the experiments would show that the interference of the waves excited by the E.M.F. of induction with the original waves in the wire changes its sign only at intervals of about seven metres.

In order to investigate the E.M.F. of induction close to the primary oscillation, where the results are of special importance, Dr. Hertz made use of the interferences which were obtained when the secondary circuit was in the third principal position, and the air space was rotated through 90deg. from the base line. The direction of the interference at the null point, which has already been considered, was taken as negative, the interference being considered positive when it was produced by the passage of waves on the side of C remote from P, which makes the signs correspond with those of the previous experiments. It must be borne in mind that the direction of the resultant E.M.F. at the null point is opposed to that of the E.M.F. of induction, and therefore the first table would have begun with a negative sign if the electrostatic E.M.F. could have been eliminated. The present experiments showed that up to a distance of three metres interference continued to occur, and always of the same sign as at the null point. It was unfortunately impossible to extend these observations to a greater distance than four metres, on account of the feebleness of the sparks, but the results obtained were sufficient to give distinct evidence of a finite velocity of propagation of the E.M.F. of induction. These observations, like the former ones,

were repeated with various lengths of the wire *s s* in order to exhibit the variation in phase, and the results obtained are given in the table below :—

TABLE III.

	0	1	2	3	4
100	-	-	-	-	0
150	-	-	0	0	0
200	0	0	0	+	+
250	0	+	+	+	+
300	+	+	+	+	+
350	+	+	+	+	0
400	-	+	+	+	0
450	-	+	+	0	0
500	-	+	0	0	0
550	-	0	0	0	-
600	0	-	-	-	-

which shows that as the distance increases the phase of the interference changes in such a manner that a reversal of sign takes place at intervals of from seven to eight metres. This result is further confirmed by comparing the results of Table III. with the results for greater distances given in Table II., for in the former series the effect of the electrostatic E.M.F. is eliminated owing to the special position of the secondary circuit, while in the former it becomes insensible at the greater distances owing to its rapid decrease with increasing distance. We should therefore expect the results given in the first table for distances beyond four metres to follow without a break the results given in Table III. for distances up to four metres. This was found to be the case, as is evident from inspection of Tables II. and III.

To show this more clearly the signs of the interference of the waves, due to the electro-dynamic E.M.F., with the waves in the wire, are collected together in Table IV., the first four columns of which are taken from Table III., and the remaining columns from Table II.

TABLE IV.

	0	1	2	3	4	5	6	7	8	9	10	11	12
100	-	-	-	-	0	0	0	+	+	+	+	+	0
250	0	+	+	+	+	+	0	0	0	0	-	-	-
400	-	+	+	+	0	0	-	-	-	-	0	0	0

From the results given in this table the author draws the following conclusions :—

(1) The interference does not change its sign at intervals of 2·8 metres. The electro-dynamic actions are therefore not propagated with an infinite velocity.

(2) The interference is not in the same phase at all points. Therefore the electro-dynamic actions are not propagated through air with the same velocity as electric waves in wires.

(3) A gradual retardation of the waves in the wire has the effect of displacing a given phase of the interference towards the origin of the waves. The velocity of propagation through the air is therefore greater than through a wire.

(4) The sign of the interference is reversed at intervals of 7·5 metres, and therefore in traversing this distance an electro-dynamic wave gains one length of the waves in the wire.

Thus, while the former travels 7·5 metres, the latter travels $7·5 - 2·8 = 4·7$ metres, and therefore the ratio of the velocities is 75 : 47, which gives for the half-wave length of the electro-dynamic action $2·8 \times 75/47 = 4·5$ metres. Since this distance is traversed in 1·4 hundred-millionths of a second, the absolute velocity of propagation through the air must be 320,000 kilometres per second. This result can only be considered reliable as far as its order is concerned; but its true value can hardly exceed half as much again, or be less than two-thirds of this amount. In order to obtain a more accurate determination of the true value it will be necessary to determine the velocity of electric waves in wires with greater exactness.

It does not necessarily follow from the fact that in the immediate neighbourhood of the primary oscillation the interference changes its sign after an interval of 2·8 metres that the velocity of propagation of the electrostatic action is infinite, forsuch a conclusion would rest upon a single change of sign, which might, moreover, be explained, independently of any change of phase, by a change in the sign of the amplitude of the resultant force at a certain distance from the primary oscillation. Quite independently, however, of any knowledge of the velocity of propagation of electrostatic actions, there exist definite proofs that the rates of propagation of electrostatic and electro-dynamic E.M.F.s are unequal.

In the first place the total force does not vanish at any point on the base line. Now, near the primary the electrostatic E.M.F. is the greater, while the electro-dynamic E.M.F. is the greater at greater distances. There must, therefore, be some point at which they are equal, and since they do not balance they must take different times to reach this point.

In the second place, the existence of points at which the direction of the resultant E.M.F. becomes indeterminate does not seem capable of explanation, except on the supposition that the electrostatic and electro-dynamic components perpendicular to each other are in appreciably different phases, and, therefore, do not compound into a rectilinear oscillation in a fixed direction. The fact that the two components of the resultant are propagated with different velocities is of considerable importance, in that it gives an independent proof that one of them at any rate must have a finite velocity of propagation.

(*To be continued.*)

THE TESLA MOTOR AND WESTINGHOUSE STATION SWITCH-BOARD ARRANGEMENT.

As announced some time ago, work has been actively prosecuted, says the *Electrical World*, by the Westinghouse Electric Company in the construction of an alternating-current motor by which the value of the alternating system as a method of power distribution is largely increased. This new motor, which is illustrated in the

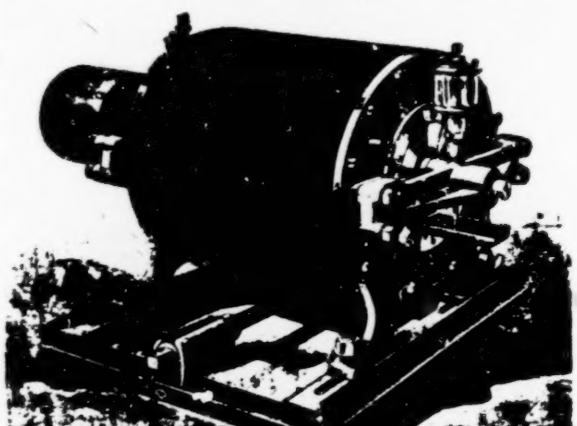

FIG. 1.

The New Westinghouse Alternating-Current Motor.

accompanying illustration (Fig. 1), is based on the method of electro-dynamic rotation devised by Mr. Nikola Tesla,* and is so constructed that no commutator or contact brush of any kind is required, the armature being without any external electrical connection, and the rotative effort being exerted entirely from the changing polarity of the field-magnets.

As will be seen, the motor consists of a series of field-magnets built up of laminated sheet iron and wound with two sets of coils, the ends of which are connected to the two binding posts shown. These binding posts form the only connection with the regular lighting circuits, with the addition of a single return wire. By the aid of this return wire two alternating currents are sent through the field of the motor at the same time, the pulsations of the two currents being equal in strength, but the one lagging a quarter phase behind the other in the two sets of field coils respectively.

* See *The Electrician*, June 15, 1888.

This gives us the value of the inverse induced current at any time during the breaking of the primary. Expand the above expression by the exponential theorem and it becomes

$$i = \frac{M}{L} I - \frac{M}{L^2} \frac{R \delta t}{1 \cdot 2} + \frac{M}{L^3} \frac{R^2 \delta t^2}{1 \cdot 2 \cdot 3} - \text{etc.}$$

At the instant when the removal of lines of force or the cessation of the induction through the secondary takes place the impressed electromotive force ceases and the secondary current begins to die away. If we suppose the "break" of the primary to be very sudden, δt becomes practically zero, and we have

$$i = \frac{M}{L} I;$$

that is to say, the secondary current starts with a value equal to $\frac{M}{L}$ of that of the steady primary.

The state of things in the secondary circuit immediately after the break of the primary is, then, this: the electromotive impulse due to stoppage of the primary has generated a current of initial value $\frac{M}{L} I$ in the secondary, but there is no impressed electromotive in the secondary circuit. If at any instant after the break the current in the secondary circuit is i, the law of decay of this current is expressed by the equation

$$L \frac{di}{dt} + R i = 0.$$

The solution of this is

$$i = C e^{-\frac{R}{L}t}$$

and the constant C is found from the condition that when $t = 0$ $i = \frac{M}{L} I$. Hence we have

$$i = \frac{M}{L} I e^{-\frac{R}{L}t} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

This gives us the value of the direct or "break" induced current in the secondary at any instant after the break of the primary. Graphically, this may be represented by a curve, such as that in Fig. 10. During the time O T in which the primary is being broken the induced electromotive force is creating an induced current, the rising strength of which is represented by the rise O P. The time occupied by the break δt is O T. As O T is diminished in value, the magnitude of the maximum ordinate P T, approximates to $\frac{M}{L} I$, and this is the initial value of the inverse secondary current when the break is very sudden. After the break the current decays away along a path represented by P Q, and becomes zero only after an infinite time.

Fig. 10.

The whole quantity of the induced current is obtained by integrating equation (7) with respect to the time from zero to infinity, thus

$$\int_0^\infty i\,dt = \int_0^\infty \frac{M}{L} I e^{-\frac{R}{L}t} = \frac{M I}{R}$$

We see, then, that both the maximum value and whole quantity of the direct secondary current are proportional to the coefficient of mutual induction and to the strength of the primary current, and, moreover, that the whole quantity of electricity set in motion in a secondary circuit of total resistance R by suddenly removing from it M I lines of force is equal to the quotient of number of lines removed by the total resistance of the secondary circuit.

If the induced current is sent through a galvanometer the indications are proportional to the magnitude of $\frac{M I}{R}$. If, however, the induced current is employed to magnetise steel needles, the magnetisation acquired is dependent upon the magnitude of $\frac{M I}{L}$, and is therefore greater in proportion as the coefficient of self-induction of the secondary circuit is less. Lord Rayleigh has pointed this out,* and shown by experiment that within certain limits the magnetising effect of the break induced current on steel needles is *greater* the smaller the number of turns of which the secondary consists, the opposite being, of course, true of the galvanometer. The galvanometer takes account of the induced current as a whole; whilst the magnetising power depends mainly on the magnitude of the current at the first moment of its formation, without regard to the time which it takes to subside.

(To be continued.)

HERTZ'S RESEARCHES ON ELECTRICAL OSCILLATIONS.

BY G. W. DE TUNZELMANN, B.SC.

(Concluded from page 18.)

The latest researches of Dr. Hertz on electrical oscillations of which accounts have been published at present are described in a Paper "On Electro-Dynamic Waves in Air, and their Reflection," in Wiedemann's *Annalen*, Vol. XXXIV., p. 609. The author had been endeavouring to find a more striking and direct proof of the finite velocity of propagation of electro-dynamic waves than those which he had hitherto given, for, though these are quite sufficient to establish the fact, they can only be properly appreciated by one who has obtained a grasp of the results of the entire series of researches.

In many of the experiments which have been described Dr. Hertz had noticed the appearance of sparks at points in the secondary conductor, where it was clear from geometrical considerations that they could not be due to direct action, and it was observed that this occurred chiefly in the neighbourhood of solid obstacles. It was found, moreover, that in most positions of the secondary conductor the feeble sparks produced at a great distance from the primary became considerably stronger in the vicinity of a solid wall, but disappeared with considerable suddenness quite close to the wall. The most obvious explanation of these experiments was that the waves of inductive action were reflected from the wall and interfered with the direct waves, especially as it was found that the phenomena became more distinct when the circumstances were such as to favour reflection to the greatest possible extent. Dr. Hertz therefore determined upon a thorough investigation of the phenomena.

The experiments were made in the Physical Lecture Theatre, which is 15 metres in length, 14 metres in width, and 6 metres in height. Two rows of iron columns, running parallel to the sides of the room, would collectively act almost like a solid wall towards electro-dynamic action, so that the available width of the room was only 8·5 metres. All pendant gas fittings were removed, and the room left empty, with the exception of wooden tables and forms, which would not exert any appreciable disturbing effect. The end wall, from which the waves were to be reflected, was of solid sandstone, with two

* *Phil. Mag.*, Ser. 4, Vol. XXXIX., 1870, p. 429.

doors in it, and the numerous gas pipes attached to it gave it, to a certain extent, the character of a conducting surface, and this was increased by fastening to it a sheet of zinc 4 metres high and 2 metres broad, connected by wires to the gas pipes and a neighbouring water pipe. Special care was taken to provide an escape for the electricity at the upper and lower extremities of the zinc plate, where a certain accumulation of electricity was to be expected.

The primary conductor was the same that was employed in the experiments described in my last Paper, and was placed at a distance of 13 metres from the zinc plate, and, therefore, two metres from the wall at the other end of the room. The conducting wire was placed vertically, so that the E.M.F.s to be considered increased and diminished in a vertical direction. The centre of the primary conductor was 2·5 metres above the floor of the room, which left a clear space for the observations above the tables and benches. The point of intersection of the reflecting surface with the perpendicular from the centre of the primary conductor will be called the point of incidence, and the experiments were limited to the neighbourhood of this point, as the investigation of waves striking the wall at a considerable angle would be complicated by the differences in their polarisation. The plane of vibration was therefore parallel to the reflecting surface, and the plane of the waves was perpendicular to it, and passed through the point of incidence.

The secondary conductor consisted of the circle of 35 centimetres radius, which has been already described. It was movable about an axis through its centre perpendicular to its plane, and the axis itself was movable in a horizontal plane about a vertical axis. In most of the experiments the secondary conductor was held

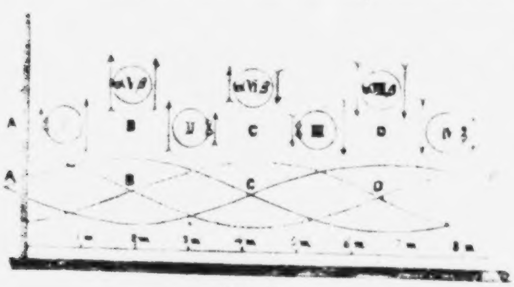

Fig. 12.

in the hand by its insulating wooden support, as this was the most convenient way of bringing it into the various positions required. The results of these experiments, however, had to be checked by observations made with the observer at a greater distance from the secondary, as the neighbourhood of his body exerted a slight influence upon the phenomena. The sparks were distinct enough to be observed at a distance of several metres when the room was darkened, but when the room remained light they were practically invisible even when the observer was quite close to the secondary.

When the centre of the secondary was placed in the line of incidence and with its plane in the plane of vibration, and the air-space was turned first towards the reflecting wall and then away from it, a considerable difference was generally observed in the strength of the sparks in the two positions. At a distance of about 0·8 metre from the wall the sparks were much stronger when the air space was directed towards the wall, and its length could be adjusted so that while there was a steady stream of sparks when in this position, they disappeared entirely when the air space was directed away from the wall. These phenomena were reversed at a distance of 3 metres, and recurred, as in the first case, at a distance of 5·5 metres. At a distance of 8 metres the sparks were stronger when the air space was turned away from the wall, as at the distance of 3 metres, but the difference was not so well marked. When the distance was increased beyond 8 metres no further reversal took place, owing to the increase in the direct effect of the primary oscillation and the complicated distribution of the E.M.F. in its neighbourhood.

The positions I., II., III., and IV. (Fig. 12) of the secondary circle are those in which the sparks were strongest, the distance from the wall being shown by the horizontal scale at the foot. When the secondary circle was in the positions V., VI., and VII., the sparks were equally strong in both positions of the air space, and quite close to the wall the difference between the sparks in the two positions again diminished. Therefore the points A, B, C, D in the diagram may in a certain sense be regarded as nodes. The distance between two of these points must, however, be taken as the half wave length, for if all the electrical motions changed their directions on passing through one of these points the phenomena observed in the secondary circle would be repeated without variation, since the direction of oscillation in the air space is indifferent.

The conclusion to be drawn from the experiments is that in passing any one of these points part of the action is reversed, while another part is not. The experimental results, however, warrant the assumption that twice the distance between two of these points is equal to the half wave length, and when this assumption is made the phenomena can be fully explained.

For, suppose a wave of E.M.F., with oscillations in a vertical direction, to impinge upon the wall, and to be reflected with only slightly diminished intensity, thus giving rise to stationary waves. If the wall were a perfect conductor, a node would necessarily be formed in its surface, for at the boundary and in the interior of a perfect conductor the E.M.F. must be infinitely small. The wall cannot, however, be considered as a perfect conductor, for it was not metallic throughout, and the portion which was metallic was not of any great extent. The E.M.F. would therefore have a finite value at its surface, and would be in the direction of the impinging waves. The node, which in the case of perfect conductivity would occur at the surface of the wall, would, therefore, actually be situated a little behind it, as shown at A in the diagram. If, then, twice the distance AB — that is to say, the distance AC — is half the wave length the steady waves will be as represented by the continuous lines in Fig. 12. The E.M.F.s acting on each side of the circles, in the positions I., II., III., and IV., will therefore at a given moment be represented in magnitude and direction by the arrows on each side of them in the diagram. If, therefore, in the neighbourhood of a node the air space is turned towards the node, the strongest E.M.F. in the circle will act under more favourable conditions against a weaker one under less favourable conditions. If, however, the air space is turned away from the node, the stronger E.M.F. acts under less favourable conditions against a weaker one under more favourable conditions. In the latter case the resultant action must be less than in the former, whichever of the two E.M.F.s has the greater effect, which explains the change of sign of the phenomenon at each quarter wave length.

This explanation is further confirmed by the consideration that if it is the true one the change of sign at the points B and D must take place in quite a different manner from that of the point C. The E.M.F.s acting on the secondary circle, in the positions V., VI., and VII., are shown by the corresponding arrows, and it is clear that in the positions B and D, if the air space is turned from one side to the other, the vibration will change its direction round the circle, and, therefore, the sparking must during the rotation vanish either once or an uneven number of times. In the position C, however, the direction of vibration remains unaltered, and therefore the sparks must disappear an even number of times, or not at all.

The experiments showed that at B and D the sparking diminished as the air space receded from α, vanished at the highest point, and again attained its original value at the point β. At C, on the other hand, the sparking continued throughout the rotation, being a little stronger at the highest and lowest points. If, then, there is any change of sign in the position C, it must occur with very much smaller displacements than in the other positions, so that in any case there is a distinction such as required between this and the other two cases.

Another very direct proof of the truth of Dr. Hertz's representation of the nature of the waves was obtained. If the secondary circle lies in the plane of the waves instead of in the plane of vibration, the E.M.F. must be equal at all points of the circle, and for a given position of the air space the sparking must be directly proportional to its intensity. When the experiment was made it was found, as expected, that at all

distances the sparking vanished at the highest and lowest points of the circle, and attained a maximum value at the points in the horizontal plane through the point of incidence.

The air space was then placed at such a point and close to the wall and was then moved slowly away from the wall, when it was found that while there was no sparking quite close to the metal plate, it began at a very small distance from it, rapidly increased, reached a maximum at the point B, and then diminished again. At C the sparking again became excessively feeble, and increased as the circle was moved still further away. The sparking continued steadily to increase after this, as the motion of the circle was continued in the same direction, owing, as before, to the direct action of the primary oscillation.

The curves shown by the continuous lines in Fig. 12 were obtained from the results of these experiments, the ordinates representing the intensity of the sparks at the distances represented by the corresponding abscissæ.

The existence in the electrical waves of nodes at A and C, and of loops at B and D, is fully established by the experiments which have been described; but in another sense the points B and D may be regarded as nodes, for they are the nodal points of a stationary wave of magnetic induction which, according to theory, accompanies the electrical wave and lags a quarter wave-length behind it.

This can easily be shown to follow from the experiments, for when the secondary circle is placed in the plane of vibration with the air space at its highest point, there will be no sparking if the E.M.F. is uniform throughout the space occupied by the secondary. This can only take place if the E.M.F. varies from point to point of the circle, and if its integral round the circle differs from zero. This integral is proportional to the number of magnetic lines of force passing backwards and forwards across the circle, and the intensity of the sparks may be considered as giving a measure of the magnetic induction, which is perpendicular to the plane of the circle. Now in this position vigorous sparking was observed close to the wall, diminishing rapidly to zero as the point B was approached, then increasing to a maximum at C, falling to a well-marked minimum at D, and finally increasing continuously as the secondary approached still nearer to the primary. If the intensities of these sparks are taken as ordinates, positive and negative, and the distances from the wall as abscissæ, the curve shown by the dotted lines in Fig. 12 is obtained, which therefore represents the magnetic waves.

The phenomena observed in the first series of experiments described in this Paper may therefore be regarded as due to the resultant electric and magnetic actions. The former changes sign at A and C, the latter at B and D, so that at each of these points one part of the action changes sign, while the other does not, and therefore the resultant action which is their product must change sign at each of these points, as was found to be the case.

When the secondary circle was in the plane of vibration the sparking in the vicinity of the wall was observed to be a maximum on the side towards the wall, and a minimum at the opposite side, and as the circle was turned from one position to the other there was found to be no point at which the sparks disappeared. As the distance from the wall was increased the sparks on the remote side gradually became weaker, and vanished at a distance of 1·08 metre from the wall. When the circle was carried further in the same direction the sparks appeared again on the side remote from the wall, but were always weaker than on the side next to it; the sparking, however, no longer passed from a maximum to a minimum merely, but vanished during the rotation once in the upper and once in the lower half of the circle. The two null points gradually receded from their original coincident positions, until at the point B they occurred at the highest and lowest points of the circle. As the circle was moved further in the same direction, the null points passed over to the side next to the wall, and approached each other again, until when the centre was at a distance of 2·35 metres from the wall the two null points were again coincident. B must be exactly half-way between this point and the similar point previously observed, which gives 1·72 metre as the distance of B from the wall, a result which agrees, within a few centimetres, with that obtained by direct observation. Moving further in the direction of C, the sparking at different points of the circle became more nearly equal, until at C it was exactly so. In this position there was no null point, and as the distance was further increased the phenomena recurred in the same order as before.

Dr. Hertz found that the position of C could be determined within a few centimetres, the determinations of its distance from the wall varying from 4·10 to 4·15 metres; he gives its most probable value as 4·12 metres. The point B could not be observed with any exactness, the direct determinations varying from 6 to 7·5 metres as its distance from the wall. It could, however, be determined indirectly, for the distance between B and C being found to be 2·4 metres, taking this as the true value, A must have been 0·68 metre behind the surface of the wall, and 6·52 metres in front of it. The half-wave length would be 4·8 metres, and by an indirect method it was found to be 4·5 metres, so that the two results agree fairly well. Taking the mean of these as the true value, and the velocity of light as the velocity of propagation, gives as the vibration period of the apparatus 1·55 hundred-millionths of a second, instead of 1·4 hundred-millionths, which was the theoretically calculated value.

A second series of experiments were made with a smaller apparatus, and though the measurements could not be made with as much exactness as those already described, the results showed clearly that the position of the nodes depends only on the dimensions of the conductors and not on the material of the wall.

Dr. Hertz states that after some practice he succeeded in obtaining indications of reflection from each of the walls. He was also able to obtain distinct evidence of reflection from one of the iron columns in the room, and of the existence of electro-dynamic shadows on the side of the column remote from the primary.

In the preceding experiments the secondary conductor was always placed between the wall and the primary conductor—that is to say, in a space in which the direct and reflected rays were travelling in opposite directions, and gave rise to stationary waves by their interference.

He next placed the primary conductor between the wall and the secondary, so that the latter was in a space in which the direct and reflected waves were travelling in the same direction. This would necessarily give rise to a resultant wave, the intensity of which would depend on the difference in phase of the two interfering waves. In order to obtain distinct results it was necessary that the two waves should be of approximately equal intensities, and therefore the distance of the primary from the wall had to be small in comparison with the extent of the latter, and also in comparison with its distance from the secondary.

To fulfil these conditions the secondary was placed at a distance of 14 metres from the reflecting wall, and, therefore, about 1 metre from the opposite one, with its plane in the plane of vibration, and its air space directed towards the nearest wall, in order to make the conditions as favourable as possible for the production of sparks. The primary was placed parallel to its former position, and at a perpendicular distance of about 30 centimetres from the centre of the reflecting metallic plate. The sparks observed in the secondary were then very feeble, and the air space was increased until they disappeared. The primary conductor was then gradually moved away from the wall, when isolated sparks were soon observed in the secondary, passing into a continuous stream when the primary was between 1·5 and 2 metres from the wall—that is, at the point B. This might have been supposed to be due to the decrease in the distance between the two conductors, except that as the primary conductor was moved still further from the wall the sparking again diminished, and disappeared when the primary was at the point C. After passing this point the sparking continually increased as the primary approached nearer to the secondary. These experiments were found to be easy to repeat with smaller apparatus, and the results obtained confirmed the former conclusion, that the position of the nodes depends only on the dimensions of the conductor, and not on the material of the reflecting wall.

Dr. Hertz points out that these phenomena, which are exactly analogous to the acoustical experiment of approaching a vibrat-

ing tuning fork to a wall, when the sound is weakened in certain positions and strengthened in others, and also to the optical phenomena illustrated in Lloyd's form of Fresnel's mirror experiments, and as these are accepted as arguments tending to prove that sound and light are due to vibration, his investigations give a strong support to the theory that the propagation of electro-magnetic induction also takes place by means of waves. They, therefore, afford a confirmation of the Faraday-Maxwell theory of electrical action. He points out, however, that Maxwell's, in common with other electrical theories, leads to the conclusion that electricity travels through wires with the velocity of light, a conclusion which his experiments show to be untrue. He states that he intends to make this contradiction between theory and experiment the subject of further investigation.

LETTERS FOR LEARNERS AND UN-PROFESSIONAL READERS.

BY H. D. WILKINSON.

SECTION II.—ELECTRO-MAGNETIC FIELDS.

(Continued from page 821, Vol. XXI.)

135. ***Electro-Magnetisation of Annealed Iron Wire.***—In order to observe the magnetisation of a piece of iron when there is practically no demagnetising effect from its own poles, it has been stated that a rod or wire must be selected whose length is at least 300 times its diameter. Now, if the magnetic moment is measured by either of the two methods of Gauss already detailed (para. 125), the iron wire tested must be very small in diameter, as it is not convenient to test a very long wire by these methods. And the strength of pole developed in a wire of small diameter is necessarily very small even when the iron has acquired a high magnetisation, in consequence of

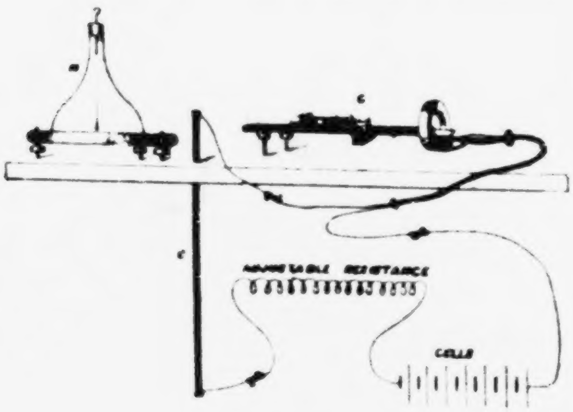

FIG. 116.

which the magnetometer can only be deflected to very small angles. With a light mirror attached to the needle, the amplitude of the deflection can be considerably increased by a ray of light reflected from the mirror on to a screen, and in this manner very small movements of the needle can be accurately observed. We are here, however, employing a magnetometer without a mirror attachment, and it is therefore advisable to arrange matters so that the needle is deflected to a considerable angle, say to 50 deg. or 60 deg., when the iron is near its highest magnetisation. The intermediate deflections can then be read with ease and accuracy. This may be effected conveniently by using a long core and placing it vertically, as shown at C (Fig. 116). As large a diameter as No. 11 B.W.G. iron wire may be used for a core 3ft. long, and yet be over the necessary ratio of length to diameter. This gives sufficient sectional area of iron to develop, at high magnetisations, enough strength of pole to strongly deflect the needle, the top end of the core being within 20 centimetres from the needle. In this diagram, C is the magnetising coil wound round a brass tube, and fixed vertically by passing it through a hole in the table. The iron wire core of the same length as the tube should slip easily into it, and the upper end of the latter be fixed a little above the level of the magnetometer needle, in order that the pole, which is formed at a little distance from the end, may act more nearly in a horizontal line with the needle. As the iron becomes more magnetised the poles move up more to the ends, but are always some slight distance off, even when most strongly magnetised. By this method the upper pole acts powerfully on the needle, and with a long core the action of the lower pole is very feeble. If we neglect the action of the lower pole, the intensity of field at the needle placed r centimetres away from the upper pole, is

$$\frac{m}{r^2} \text{ C.G.S. units,}$$

where m is the strength of pole (see paras. 108 and 109). But where accuracy is required the action of the lower pole must be taken into account. Taking the point of p (Fig. 117) as the centre of the magnetometer needle and SN as the magnetised core, it will be seen that the lower pole (R centimetres from p) would repel a unit north pole at p with a force of

$$\frac{m}{R^2} \text{ dynes.}$$

But this force is in an oblique direction, and the needle moving in a horizontal plane is only influenced by horizontal forces. It is therefore only the horizontal component of the above force that we have to deal with. Resolving by the parallelogram of forces we have by similar triangles

$$r : \text{horizontal component} :: \frac{m}{R^2} : R,$$

whence the horizontal force $= \frac{mr}{R^3}$ dynes.

FIG. 117.

The resultant force f at the needle is then the difference between the forces due to each pole, viz.,

$$\frac{m}{r^2} - \frac{mr}{R^3} \text{ dynes.}$$

Now, the force in dynes on unit pole at a point is the same thing as the intensity of field at that point, and, therefore, the above value of f represents the strength of field at the needle centre due to both poles of the core. This field also acts on the needle at right angles to the earth's horizontal field H, and therefore (by para. 119)

$$f = H \tan a,$$

where a is the angular deflection of needle. Glancing at the figure it will be noticed that the end of the magnetometer needle is viewed, the earth's meridian being supposed to be at right angles to the plane of the paper, and the magnetising coil C being placed east or west of the needle.

HERTZ'S RESEARCHES ON ELECTRICAL OSCILLATIONS.

BY G. W. DE TUNZELMANN, B.Sc.

(Continued from page [illegible].)

It was shown in the experiments described in my last Paper that when variable electrical forces act in the interior of dielectrics of specific inductive capacity not equal to unity, the corresponding electric displacements produce electrodynamic effects. In a paper "On the Velocity of Propagation of Electro Dynamic Actions," in Wiedemann's *Annalen*, Vol. XXXIV., p. 551, Dr. Hertz shows that similar actions take place in the air, which proves, as was previously pointed out, that electrodynamic action must be propagated with a finite velocity.

The method of investigation was to excite electrical oscillations in a rectilinear conductor in the same manner as in former experiments, and then to produce effects in a secondary conductor by exciting electrical oscillations in it by means of those in the rectilinear conductor, and at the same time by the primary conductor acting through the intervening space. This distance was gradually increased, when it was found that the phase of the vibrations at a distance from the primary lagged behind those in its immediate neighbourhood, showing that the action is propagated with a finite velocity, which was found to be greater than the velocity of propagation of electrical waves in wires in the ratio of about 45 to 28, so that the former is of the same order as the velocity of light. Dr. Hertz was unable to obtain any evidence with respect to the velocity of propagation of electrostatic actions.

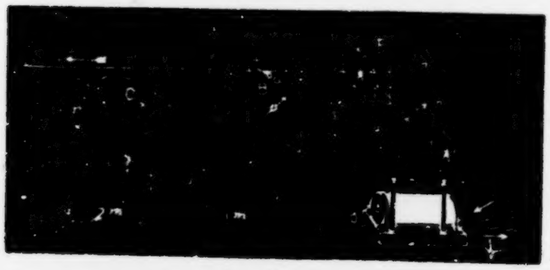

FIG. 11.

The primary conductor A A' (Fig. 11) consisted of a pair of square brass plates with sides 40 centimetres in length, connected by a copper wire 60 centimetres in length, at the middle point of which was an air space, across which sparks were made to pass by means of powerful discharges from the induction coil. The conductor was fixed at a height of 1.5 metre above the base plate of the coil, with its plates vertical and the connecting wire horizontal. A straight line, drawn horizontally through the air space of the primary and perpendicular to the direction of the primary oscillation will be called the base line, and a point in this situated at a distance of [illegible] centimetres from the air space will be referred to as the null point.

The experiments were made in a large lecture room, with nothing near the base line for a distance of 12 metres from the primary conductor. The room was darkened during the experiments.

The secondary conductor consisted either of a circular wire, [illegible] centimetres radius, or of a square of wire, B, with [illegible] centimetres side. The primary and secondary air spaces were both capable of adjustment by means of micrometer screws. Both the secondary conductors were in unison with the primary, the half vibration period of each being 1.4 hundred-millionths of a second, as calculated from the capacity and coefficient of self-induction. It is doubtful whether the ordinary theory of electrical oscillations would lead to accurate values under the conditions of these experiments, but as it gives correct numerical results in the case of Leyden jar discharges, it may be expected to be correct as far as the order of the results is concerned. When the centre of the secondary lies in the base line and its plane coincides with the vertical plane through the [illegible] no sparks are observed in the secondary, the E.M.F. [illegible] everywhere perpendicular to the direction of the [illegible]. This will be referred to as "the first principal position" [illegible] secondary. When the plane of the secondary is [illegible] perpendicular to the base line, the centre still [illegible] base line, the secondary will be said to be in [illegible] principal position." Sparking then occurs in the [illegible] its air space is either above or below the [illegible] through the base line, but not when it is in this [illegible] the distance from the primary was increased [illegible] distance was observed to decrease [illegible] ultimately very slowly. Sparks were [illegible] the whole distance of 12 metres available [illegible]. The sparking in this position is due [illegible] produced in the portion of the secondary [illegible] space. The total E.M.F. is partly [illegible] electrodynamic, and the experiments show [illegible] [illegible] of doubt that the former is greater [illegible] determines the direction of the total E.M.F. [illegible] primary, while at greater distances it is the electro[illegible] E.M.F. which is the greater.

The plane of the secondary was then turned [illegible] horizontal, its centre still lying in the base line. This [illegible] called "the third principal position." When [illegible] circular secondary conductor was kept fixed at the null [illegible] and the air space was made to travel round the circle [illegible] sparking was observed in all positions. The sparking [illegible] attained its maximum length of about six millimetres [illegible] air space was nearest to that of the primary, and its [illegible] length of about three millimetres when the distance [illegible] the two air spaces was greatest. If the secondary [illegible] influenced by the electrostatic force, sparking would [illegible] expected when the air space was close to the [illegible] cessation of sparks in the intermediate positions [illegible] tion of the oscillations would, moreover, be [illegible] direction of the E.M.F. in the portion of the secondary [illegible] from the air space. There is, however, superposed [illegible] electrostatically excited oscillation a second [illegible] the E.M.F. of induction, which produces a [illegible] since its integral round the circle considered [illegible] does not vanish, and the direction of this [illegible] independent of the position of the air space [illegible] electrostatic E.M.F. in the portion of the [illegible] A A', and assisting it in the portion furthest from A A', [illegible] explained in a previous Paper.

The electrostatic and electrodynamic E.M.F.s [illegible] act in the same direction when the air space is turned towards the primary conductors, and in opposite directions when the air space is turned away from the primary. In the [illegible] position it is the E.M.F. of induction which is the [illegible] ful, as is shown by the fact that there is no [illegible] sparking in any position of the air space. For when the [illegible] degrees to the right or left of the base line it coincides with [illegible] node with respect to the electrostatic E.M.F. In these [illegible] tions the inductive action in the neighbourhood of the [illegible] can be observed, independently of the electrostatic [illegible].

Waves in Rectilinear Wires.—In order to produce [illegible] by means of the primary oscillations a series of [illegible] waves of the character required for these experiments, the following arrangements were made. Behind the plate A' [illegible] placed a plate, P, of equal size. A copper wire [illegible] in diameter connected P to the point M of the [illegible] M the wire was continued in a curve about [illegible] to the point N, situated about [illegible] centimetres above the [illegible] space, and was then further continued in a straight line parallel to the base line for such a distance as to [illegible] danger of disturbance from reflected waves. In the [illegible] series of experiments the wire passed through a [illegible] and after being carried to a distance of about [illegible] was put to earth, and a special series of experiments [illegible] the length was sufficient. When a wire bent into a nearly closed circuit with a small air space was brought near to this straight wire, a series of fine sparks was seen to accompany the discharges of the induction coil. These [illegible] could be varied by varying the distance between the [illegible]

[illegible] waves in the rectilinear wire were of the [illegible] as that of the primary oscillations, as was [illegible] their being shown to be in unison with each [illegible] secondary conductors previously described [illegible] of stationary waves showed that the waves [illegible] wire were of a steady character in space as [illegible] time. The nodal points were determined in the [illegible] manner: The further end of the wire was left free, [illegible] secondary conductor was brought near to it, in such [illegible] that the wire lay in its plane, and had the air space [illegible] it. As the secondary was moved along the [illegible] of no sparking were observed to recur periodically. [illegible] from the point a to the first of these was [illegible], and the length of the wire made equal to a multiple [illegible] distance. The experiments were then repeated, and it [illegible] that the nodal points occurred at approximately [illegible] intervals along the wire.

[illegible] nodes could also be distinguished from the loops in [illegible] ways. The secondary conductor was brought near to [illegible] with its plane perpendicular to it, and with its air [illegible] neither directed completely towards the wire nor com[illegible] away from it, but in an intermediate position, so as to [illegible] E.M.F.s perpendicular to the wire. Sparks were then [illegible] at the nodes, while they disappeared at the loops. [illegible] sparks were taken from the rectilinear wire by means [illegible] insulated conductor, they were found to be stronger at [illegible] nodes than at the loops; the difference, however, was [illegible] and was, indeed, scarcely distinguishable unless the [illegible] of the nodes and loops was previously known. The [illegible] that this and other similar methods do not give a well [illegible] result lies in the fact that irregular oscillations are [illegible] upon the waves considered; the regular waves, [illegible], can be picked out by means of the secondary, just [illegible] notes are picked out by means of a Helmholtz reso[illegible]. If the wire is severed at a node, no effect is produced [illegible] the waves in the portion of wire next to the origin; but [illegible] the severed portion of wire is left in its place, the waves [illegible] to be propagated through it, though with somewhat [illegible] strength.

[illegible] possibility of measuring the wave lengths leads to [illegible] applications. If the copper wire hitherto used is re[illegible] by one of different diameter, or by a wire of some other [illegible] the nodal points retain their position unchanged. It [illegible] from this that the velocity of propagation in a wire [illegible] definite value independent of its dimensions and material. [illegible] iron wires offer no exception to this, showing that the magnetic susceptibility of iron does not play any part in the [illegible] of such rapid motions. It would be interesting to investi[illegible] the behaviour of electrolytes in this respect. In their case we should expect a smaller velocity of propagation, because [illegible] electrical motions are accompanied by motions of the mole[illegible] carrying the electric charges. It was found that no propagation of the waves took place through a tube 10 millimetres in diameter, filled with a solution of sulphate of copper; but this may have been due to the resistance being too high. By the measurement of wave lengths the relative vibration periods of different primary conductors can be determined, and it therefore becomes possible to compare in this manner the vibration periods of plates, spheres, ellipsoids, &c.

In the experiments made by Dr. Hertz nodes were very distinctly produced when the wire was severed at a distance of either 8 metres or 5.5 metres from the null point of the base line. In the first case the nodes occurred at distances from the null point of −0.2 metre, 2.3 metres, 5.1 metres, and [illegible] metres, and in the latter case at distances of −0.1 metre, [illegible] metres, and 5.5 metres. It appears, therefore, that the (half) wave length in a free wire cannot differ much from [illegible] metres. The fact that the wave lengths nearest to P were somewhat smaller was to be expected from the influence of the plates and of the curvature of the wire. This wave length, with a period of 1.4 hundred millionths of a second, gives 200,000 kilometres per second for the velocity of propagation of electrical waves in wires. Fizeau and Gounelle (Poggendorff's *Annalen*, Vol. LXXX., p. 158, 1850) obtained for the velocity in iron wires 100,000 kilometres per second, and 180,000 in copper wires. W. Siemens (Poggendorff's *Annalen*, Vol. CLVII., p. 309, 1876), by the aid of Leyden jar discharges, obtained a velocity of from 200,000 to 260,000 kilometres per second in iron wires. Dr. Hertz's result is very nearly the mean of these, from which we may conclude that the order at any rate, of the vibration period as calculated by him is correct. The value obtained cannot be regarded, independently of its agreement with experimental results otherwise obtained, as a fresh determination of the velocity, since it rests upon a theory which is open to doubt.

(To be continued.)

THE ELECTROLYTIC PURIFICATION OF ALCOHOL.

M. Pouthiere, of the University of Louvain, has published some interesting information with regard to the methods employed in France for purifying the products of the distillation of various substances containing sugar or starch, by means of the electrolytic process of M. Naudin. The alcohol of beetroot, for instance, when subjected to this treatment, and afterwards rectified in the usual manner, is entirely free from the unpleasant smell which characterises the crude product; whilst the alcohol of the Jerusalem artichoke, which is, as a rule, completely useless, yields as good results if treated by the Naudin process as that distilled from maize.

The earliest attempts in this direction were made by M. Eisenmann, who, although he employed electricity, made no use of electrolysis. M. Eisenmann passed a current of ozonised air at 70 C. through the liquid to be purified. To ozonise the air, it was sent through a glass tube placed between the terminals of an inductive coil. This process certainly oxidised some of the deleterious constituents of the liquid, but did not seem to act on the aldehydes which form the principal impurity of crude alcohol.

In the Naudin process the liquid is first hydrogenised by means of a Gladstone and Tribe zinc copper element. At M. Boulet's works, at Bapaume lez Rouen, wood or iron vats are used containing a number of zinc plates which are alternately flat and corrugated. The weight of zinc in a 150 hectolitre (3,300 gals.) vat is 6,200 kg. (6 tons); the number of plates is 105, and the active surface equals 1,800 square metres (19,800 square feet). Sulphate of copper is dissolved in the alcohol to be treated, and the reduced copper is deposited on the zinc plates. Five solutions containing [illegible] per cent. of copper sulphate are employed in succession. The total weight of copper deposited is 360 kg. (0.36 tons) in the case of the 150 hectolitre vat. The temperature at which the deposit is made is a matter of supreme importance; it ought to be from 30 C. to 35 C.; five degrees more or less injuriously affect the process. If the temperature is too low, the action ceases; if it is too high, the copper does not adhere firmly to the zinc plates. Each solution requires 24 hours to completely deposit the copper contained in it, so that the entire zinc copper process requires five days. Owing to the formation of oxidised zinc hydrate, 5 kg. of hydrochloric acid are added every week for every 150 hectolitres of alcohol treated.

The above process is generally sufficient to completely purify the crude alcohol, but owing to the presence of other impurities it is sometimes necessary to employ electrolysis before rectification. The voltameters in which this latter process takes place are glass cylinders 125mm. in diameter and 60mm. long, furnished with ebonite caps, through which pass the copper electrodes and the supply and overflow pipes. To treat 300 hectolitres in twenty four hours M. Naudin employs twelve voltameters, two in series and six in parallel, using a total current of 36.65 amperes and an E.M.F. of 113.5 volts. The current is furnished by a four horse power Siemens shunt-wound dynamo. To neutralise the small quantity of hydrochloric acid employed to acidulate the solution some zinc is placed in the vat supplying the still in which the spirit is rectified.

M. Naudin has furnished the following figures as to the cost of each of the above operations in producing one hectolitre (twenty-two gallons) of pure alcohol.

Treatment of 300 hectolitres of products of the first distillation by the zinc-copper process in twenty four hours.

Commercial hydrochloric acid, 1.25 kilog., at 6fr. the 100 kilog.	·075fr.
Sulphate of copper, 1.25 kilog., at 56fr. the 100 kilog. zinc consumed	·70 „
By the acid or sulphate of copper, 2 kilog. / By the liberation of hydrogen, 1.5 kilog., at 60fr. the 100 kilog.	2·10 „
Labour, 24 hours	7· „
Power	2· „
Maintenance and repairs	1·50 „
Depreciation, 15,000fr. in ten years	4·50 „
Total	17·875fr.

HERTZ'S RESEARCHES ON ELECTRICAL OSCILLATIONS.

BY G. W. DE TUNZELMANN, B.SC.

(*Continued from page 726.*)

Dr Hertz's next Paper in order of publication in Wiedemann's *Annalen*, "On Some Induction Phenomena arising from Electrical Actions in Dielectrics" (Wiedemann's *Annalen*, Vol XXXIV., p. 273), contains an account of some researches undertaken with a view of obtaining direct experimental confirmation of the assumption involved in the most suggestive theory of electrical actions, viz., that of Faraday and Maxwell, that the well known electrostatic phenomena observed in dielectrics are accompanied by corresponding electro-dynamic actions. The method of observation consisted in placing a secondary conductor adjusted to unison, as regards electrical oscillations, with the primary, as near as possible to the former, and in such a relative position that the sparks in the primary produced no sparking in the secondary. As the equilibrium could be disturbed and sparking induced in the secondary by the approach of conductors, it formed a kind of induction balance; but the point of special interest in connection with it was that a similar effect was produced when the conductors were replaced by insulators, provided the latter were of comparatively large size. The observed rapidity of the oscillations induced in the dielectrics showed

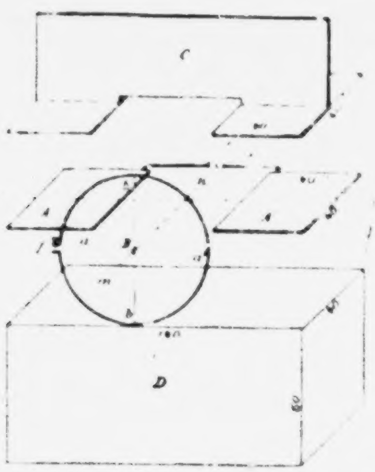

FIG. 10.

that the quantities of electricity in motion under the influence of dielectric polarisation were of the same order of magnitude as in the case of metallic conductors.

The apparatus employed is shown diagrammatically in Fig. 10, and was supported on a light wooden framework, not shown in the illustration. The primary conductor consisted of two brass plates, A A', with sides 40 centimetres in length, joined by a copper wire 70 centimetres long and half a centimetre in diameter, containing an air space of three quarters of a centimetre, with terminals formed of polished brass spheres. When placed in connection with a powerful induction coil, oscillations are set up, the period of which, determined by the dimensions of the primary, can be determined to within a hundred millionth of a second. The secondary conductor consisted of a circle, 35 centimetres in radius, of copper wire two millimetres in diameter, containing an air space, the length of which could be varied by means of a screw from a few hundredths of a millimetre, up to several millimetres. The dimensions stated were such as to bring the two conductors into unison, and secondary sparks up to six or seven millimetres in length could be obtained.

The circle was movable about an axis through its centre perpendicular to its plane, to enable the position of the air space to be varied. The axis was fixed in the position *m n* in the plane of A and A', and halfway between them. The centre of the circle was at a distance of 12 centimetres from the nearest points of A and A'.

When *f* was in either of the positions *a* or *a'* lying in the plane of A A' no sparking occurred in the secondary, while maximum sparking took place at *b* and *b'* 90° from the former positions. The E.M.F. giving rise to the secondary sparks is, as in previous experiments, partly electrostatic and partly electromagnetic, and the former being the greater will determine the sign of the resultant E.M.F. The oscillations must, for the reason previously explained, be considered as produced in the part of the secondary most remote from the air space. Assuming the E.M.F. and the amplitude of the resulting oscillation to be positive when *f* is in the position *b'*, they will both be negative when *f* is at *b*.

When the circle was slightly lowered in its own plane the sparking distance was increased at *b'* and diminished at *b*, and the null points lay at a certain distance below *a* and *a'*. The electrostatic E.M.F. is scarcely affected by such a displacement, but the integral of the E.M.F. of induction taken round the circle is no longer zero, and therefore gives rise to an oscillation which will be of positive sign whatever be the position of *f*, for the direction of the resultant E.M.F. of induction is opposite to that of the electrostatic E.M.F. in the upper half of the circle, and coincides with it in the lower half where the electrostatic E.M.F. has been assumed to be positive. Since the new oscillation so produced is in the same phase as the previously existing one their amplitudes must be added to give the resultant amplitude, which explains the phenomena.

Effects of the Approach of Conductors.—In making these observations it was found necessary to remove all conductors to a considerable distance from the apparatus, in order to obtain a complete disappearance of sparking at the points *a* and *a'*. Even the neighbourhood of the observer was sufficient to set up sparking when the air space *f* was in either of these positions, and the sparks had therefore to be observed from a distance. The conductors used for the experiments was of the form shown at C (Fig. 10), and consisted of thin metal foil. The objects kept in view in selecting the material and dimensions were to obtain a conductor which would give a moderately large effect, and having an oscillation period less than that of the primary.

When the conductor C was brought near to A A', it was found that the sparking distance decreased at *b* and increased at *b'*, and the null points were displaced upwards—that is, in the direction of C.

From the results of experiments already described it is evident that the effect of displacing A A' upwarde would be the same, qualitatively, as that of a current in the same direction as that in A A' directly above it. The effect produced by the approach of C was the reverse of this, and could be explained by an inductive action, supposing there were a current in C in the opposite direction to that in A A', which is exactly what must occur; for the electrostatic E.M.F. would give rise to such a current, and since the oscillations in C are more rapid than those of this E.M.F., the current must be in the same phase as the inducing E.M.F. The truth of this explanation was confirmed by the following experiments. The horizontal plates of the conductor C being left in the same position as before, the vertical plate was removed, and successively replaced by wires of increasing length and fineness, in order to lengthen the oscillation period of C. The effect of this was to displace the null points more and more in an upward direction, while at the same time they became less sharply defined, a minimum sparking taking the place of the previous absolute disappearance. The sparking distance at the highest point had previously been much less than at the lowest point, but after the disappearance of the null points it began to increase. At a certain stage the sparking distance at the two positions became equal, and then no definite minimum points could be found, but sparking took place freely at all positions of *f*. Beyond this stage the sparking distance at the lowest point diminished, and very soon two minimum points made their appearance close to it, not clearly defined at first, but gradually becoming more distinct, and at the same time

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approaching the points $a\,a'$, with which they ultimately coincided, when the minimum points again became absolute null points. These results are in agreement with the conclusion drawn from the former observations, for as the oscillation period of C approaches that of A A', the intensity of the current in the former increases, but a difference of phase arises between it and the exciting E.M.F. When the two are in unison the current in C attains its maximum, and, as in other cases of resonance, the difference of phase gives rise to a slightly damped oscillation, having a period of about a quarter that of the original one, which makes any interference between the oscillations excited in the circle B by A A' and C respectively impossible. These conditions clearly correspond to the stage at which the sparking distances at b and b' were equal. When the oscillation period of C becomes decidedly greater than that of A A', the amplitude of the oscillation in the former will again diminish, so that the difference in phase between it and the exciting E.M.F. will approach half of the original period. The current in C will therefore always be in the same direction as that in A A', so that interference between the two oscillations excited in B will again become possible, and the effect of C will then be opposite to its original effect. When the conductor C was made to approach A A' the sparks in B became much smaller, which is explained by the fact that its effect will be to increase the oscillation period of A A', and therefore to throw it out of unison with B.

Effects of the Approach of Dielectrics.—A very rough estimate shows that when a dielectric of large mass is brought near to the apparatus, the quantities of electricity set in motion by dielectric polarisation are at least as large as in metallic wires or thin rods. If, therefore, the action of the apparatus were unaffected by the approach of such masses it would show that, in contradiction to the theories of Faraday and Maxwell, no electro-dynamic actions are called into play by means of dielectric polarisation, or, as Maxwell calls it, electric displacement. The experiments, however, showed an effect similar to that which would be produced if the dielectric were replaced by a conductor with a very small oscillation period. In the first experiment made, the mass of dielectric consisted of a pile of books, 1·5 metre long, 0·5 metre broad, and 1 metre high, placed under the plates A A. Its effect was to displace the null points through about 10° towards the pile. A block of asphalt (D, in Fig. 10), weighing 800 kilogrammes, and measuring 1·4 metre in length, 0·4 metre in breadth, and 0·6 metre in height, was then used in place of the books, the plates being allowed to rest upon it.

The following results were then obtained:—

(1.) The spark at the highest point of the circle was now decidedly stronger than that at the lowest point, which was nearer to the asphalt.

(2.) The null points were displaced through about 23° downwards—that is, in the direction of the block—and at the same time were transformed into mere points of minimum sparking, a complete disappearance being no longer obtainable.

(3.) When the plates A A rested on the asphalt block the oscillation period of the primary was increased, as shown by the fact that the period of B had to be slightly increased in order to obtain the maximum sparking distance.

(4.) When the apparatus was moved gradually away from the block its action steadily diminished without changing its character.

(5.) The action of the block could be compensated by bringing the conductor C over the plates A A', while they rested on the block, the null points being brought back to a and a' when C was at a height of 11 centimetres above the plates. When the upper surface of the asphalt was 5 centimetres below the plates compensation was obtained when C was placed at a height of 17 centimetres above them, showing that the action of the dielectric was of the order of magnitude which had been anticipated.

The asphalts contained about 5 per cent. of aluminium and iron compounds, 40 per cent. of calcium compounds, and 17 per cent. of quartz sand. In order to make sure that the observed effects were not due to the conductivity of some of these substances, a number of further experiments were made.

In the first place the asphalts was replaced by a mass of the same dimensions of the so-called artificial pitch prepared from coal, and effects of a similar kind were observed, but slightly weaker, the greatest displacement of the null points amounting to 19°. Unfortunately this pitch contains free carbon, the amount of which it is difficult to determine, and this would have some conductivity.

The experiments were then repeated with a conductor, C, of half the linear dimensions of the former one, and smaller blocks of various substances, on account of the great cost of obtaining large blocks of pure materials. The substances used were asphalt, coal pitch, paper, wood, sandstone, sulphur, paraffin, and also a fluid dielectric, namely petroleum. With the smaller apparatus it was not possible to obtain quantitative results of the same accuracy as before, but the effects were of an exactly similar character, and left little room for doubt of the reality of the action of the dielectric.

The results might possibly be supposed to be due to a change in the distribution of the electrostatic E.M.F. in the neighbourhood of the dielectric, but in the first place Dr. Hertz states that he has been unable to explain the details of the observations on this hypothesis, and in the second place it is disproved by the following experiment.

The smaller apparatus was placed with the line $r\,s$ on the upper near corner of one of the large blocks, in which position the dielectric was bounded by the plane of the plates A A and the perpendicular plane through $r\,s$, both of which are equipotential surfaces, so that if the action were electrostatic no effect should be produced by the dielectric. It was found, however, to produce the same effect as in other positions. It might also be supposed that the effects were due to a slight conductivity, but this could hardly be the case with such good insulators as sulphur and paraffin. Suppose, moreover, that the conductivity of the dielectric is sufficient to discharge the plate A in the ten thousandth of a second, but not much more rapidly. Then, during one oscillation, the plates would lose only the ten thousandth part of their charge, and the conduction current in the substance experimented on would not exceed the ten thousandth part of the primary current in A A, so that the effect would be quite insensible.

(To be continued.)

REVIEWS.

Traite Elementaire de l'Accumulateur Voltaique. By Emile Reynier. (Paris: Baudry and Co.) 1888.

Taken as a whole this book may be pronounced to be well worth the attention of all who are interested in the construction or the management of accumulators. The work is divided into four parts, dealing respectively with elementary principles, a description of various types of cells, technological data, and practical applications. In each section much useful matter is to be found, but in the author's desire to serve the *l'intérêt supérieur de la vérité* by discriminating between real inventions and mere adaptations, some curious omissions result. Of course, a book written by a Frenchman for Frenchmen is necessarily French, and it is no matter for surprise that the principal part is occupied with Gallic inventions. But, judging from the rate at which accumulators are being made both in England and Belgium, it seems strange that only a few pages should be given to the "foreign" manufacturer. We are disposed to attribute this to the patriotism of the author.

Chapter IV. contains sketches of some plates perhaps not generally known in England to the ordinary electrician, though most of them have been tried in approximately the same form by more than one manufacturer in this country. The Faure-Sellon-Volckmar type is briefly discussed, and some comparative tables are given, showing weights, outputs, &c., for lighting and traction cells. The use of oxygenated water with the electrolyte, according to the author, gives an increased rate of discharge, a higher voltage, and a greater capacity. Non-oxidisable sulphates are also mentioned as possessing the same virtue. But, unfortunately, we are told that this increase of activity results in damage to the plate, as ordinarily made.

No. of Trial.	Time of passage of current in seconds.	Voltameter coupled in circuit.	Area of each compound electrode. sq. cm.	Capacity k, inserted in A.	Cardew reading.	Corresponding mean alternating voltage. Volts.	Length of tube filled by gas. cm.	Corresponding vol. c.c.	Equivalent current, c, absolute units.	Calculated vol. V, c.c.	Vol. corrected to temp. 19° C.	Ratio of observed vol. to calculated vol.	Density of current per sq. cm. of either electrode in amperes.
1	600	1, 2, 3, 4, 5, 6	21·56 × 10	4	87° 45′	97·3	5·15	1·383	12·4 × 10	20·87	22·32	0·062	1·12
2	300	4, 5, 6	3·02 × 10	4	87°	96·8	18·7	5·02	2·39 × 10	12·37	13·23	0·380	7·9
3	210	5, 6	0·75 × 10	4	85° 30′	95·7	30·55	8·20	2·36 × 10	9·78	10·46	0·784	31·5
4	120	6	0·165 × 10	4	82°	93·1	9·3	2·50	1·15 × 10	2·38	2·55	0·930	69·7
5	180	6	0·165 × 10	4	84° 20′	94·8	27·7	7·44	2·34 × 10	7·27	7·78	0·956	141·8
6		6	0·165 × 10	4	83°	93·9	On	making	contact one of the electrode of couple No. 6 burned.				
7	180	one of 5 and opposite of 6	0·585 × 10; 0·165 × 10	4	85° 15′	96·4	27·75	7·45	2·35 × 10	7·31	7·82	0·953	av. 62·6
8	180	ditto	ditto	2	81°	92·4	11·65	3·13	1·14 × 10	3·54	3·78	0·836	av. 30·4
9	180	ditto	ditto	5	82°	93·9	19·05	5·11	1·73 × 10	5·35	5·72	0·893	av. 30·1
10	—	ditto	ditto	5	80°	91·9	On	making	contact the other electrode of No. 6 burned.				
11	120	5	0·585 × 10	5	85°	95·3	24·5	6·57	2·93 × 10	6·09	6·51	1·004	50·1
12	120	5	0·585 × 10	5	85° 15′	95·4	24·5	6·57	2·94 × 10	6·10	6·53	1·006	50·1
13	600	5	0·585 × 10	*72ω	80° 20′	92·1	26·25	7·04	1·22 × 10	12·65	13·53	0·520	20·9
14	135	5	0·585 × 10	*Lamp off-	78° 00′	90·4	30·80	8·26	3·47 × 10	8·09	8·65	0·955	59·3
15	135	5	0·585 × 10	ering 230ω	78° 00′	90·4	30·65	8·22	3·47 × 10	8·09	8·65	0·950	59·3

* Resistance inserted in place of A.

decomposed by a continuous current, c, in absolute measure equivalent to the passage of this quantity, Q, we have

$$c = n\,\pi\,e\,l \times 10^{-7} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and

$$V_0 = 5{\cdot}43\,\hat{n}\,e\,k\,t \times 10 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Besides the Cardew voltmeter steady potential indication, a quadrant electrometer, not shown in the diagram, with its needle connected to one pair of quadrants, was employed to measure the potential difference at the voltameter terminals, and thus indicate its mean resistance.

The above table gives the results of ten measurements. The volume of the gas is corrected for temperature, but no correction is introduced for the barometric pressure or the tension sustained by the gas in the tube.

The condenser used was adjustable from 0·001 up to 5 microfarads, and is probably accurate to at least 0·5 per cent.

The last two columns show that—

When the density of current per square centimetre of either electrode was	The percentage of gas actually generated of that calculated as due was
1·12 ampere	6·2 per cent.
7·9	38 ,,
30·01 (average)	82·6 ,,
31·35	78·4 ,,
46·1 (average)	89·3 ,,
50·1	100·8 ,,
62·6 (average)	95·3 ,,
69·7	93·0 ,,
141·8	95·6 ,,

The trials Nos. 13, 14, and 15 were taken without condenser, and with non-inductive resistances in its place. In trial No. 13 this resistance was a length of fine platinum wire (hot). In trial Nos. 14 and 15 the resistance was a 96 volt 10 candle power Edison lamp, offering 230 ohms resistance at equivalent illumination. In calculating the current strengths for these three observations, the resistance of the voltameter itself was required. It was measured in two ways—1st, by means of the quadrant electrometer, and the potential differences it indicated on the known resistance, and on the voltameter; 2nd, by rapidly substituting a non-inductive resistance alternately with the voltameter in the lamp circuit, and adjusting this resistance until the illumination was equal in both cases. These two methods concurred in showing the resistance of the voltameter to be 30 ohms, and the maximum resistance it offered through the whole series was 35 ohms.

The table shows that

When the current density per square centimetre of either electrode was—	The per cent. of calculated gas actually liberated was—
20·9	52
59·3	95·3

These results, corroborated by several previous series, go to show that for a rate of alternation of 200 per second, and currents of between 0·1 and 0·35 amperes, the quantity of gas generated by an alternating current in a voltameter is approximately equal to that generated by an equal continuous current when the mean current density at the surface of the electrode is above 50 amperes per square centimetre of each; that below that density the quantity of gas developed rapidly diminishes, and that below one ampere per square centimetre soon disappears.

Also that the resistance of a voltameter with very small plates, traversed by an alternating current, is much less than that it would offer to an equal continuous current. Were this not the case, the resistance of a voltameter for alternating current measurements might for many purposes prove prohibitively great.

HERTZ'S RESEARCHES ON ELECTRICAL OSCILLATIONS.

BY G. W. DE TUNZELMANN, B.Sc.

(Continued from page [illegible].)

Other Positions of the Secondary Circuit.—Dr. Hertz made numerous observations with the secondary circuit in other positions, but in no case were any phenomena observed which were not completely in accordance with theory. As an example of these consider the following experiment.

The secondary was first placed in the horizontal plane in the position V. (Fig. 8*), and the air space was in the position [illegible] relatively to the primary. The circle was then turned about a horizontal axis through its centre and parallel to the primary, so as to raise the air space above the horizontal plane. During this rotation θ remained equal to 90°, and the value of β remained nearly constant, but α varied approximately in the same ratio as cos Ψ, Ψ being the angle between the plane of the circle and the horizontal, for α is proportional to the number of magnetic lines of force passing through the circle. Let α_0 be the value of α in the initial position, then in the other positions its value would be $\alpha_0 \cos \Psi$, and therefore the sparking distance should be given by the expression $\alpha_0 \cos \Psi + \beta$, in which α_0 was known to be greater than β. This was confirmed by observation, for it was found that as the air space increased its height above the horizontal plane the sparking distance diminished from 6 millimetres down to 2 millimetres, its value when the air space was at its greatest distance above the horizontal plane. During the rotation through the next quadrant the sparking distance diminished almost to zero, and then increased to the smaller maximum of 2·5 millimetres, which it attained when the circle had turned though 180°, and was therefore again horizontal. Similar results were obtained in the opposite order, as the circle was rotated from 180° to 360°. When the circle was kept with the air space at its maximum

* See *The Electrician*, October 5th, 1888, page 697.

height above the horizontal plane, and then raised or lowered bodily without rotation, the sparking distance was found to diminish in the former case and to increase in the latter, results completely in accordance with theory.

Forces at Greater Distances.—Experiments with the secondary at greater distances from the primary are of great importance, as the distribution of E.M.F. in the field of an open circuit is very different according to different theories of electrodynamic action, and the results may, therefore, serve to eliminate some of them as untenable. In making these experiments, however, an unexpected difficulty was encountered, as it was found that at distances of from 1 to 1·5 metres from the primary the maximum and minimum, except in certain positions, became indistinctly defined; but when the distance was increased to upwards of two metres, though the sparks were then very small, the maximum and minimum were found to be very sharply marked when the sparks were observed in the dark. The positions of maximum and minimum were found to occur with the circle in planes at right angles to each other. At considerable distances the sparking diminished very slowly as the distance was increased. Dr. Hertz was not able to determine an upper limit to the distance at which sensible effects took place, but in a room 14 metres by 12, sparks were distinctly observed when the primary was placed in one corner of the room, wherever the secondary was placed. When, however, the primary was slightly displaced, no effects could be observed, even when the secondary was brought considerably nearer. The interposition of solid screens between the two circuits greatly diminished the effect.

Dr. Hertz mapped out the distribution of force throughout the room by means of chalk lines on the floor, putting stars at the points where the direction of the E.M.F. became indeterminate. A portion of the diagram obtained in this manner is

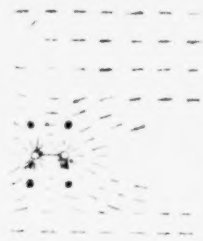


FIG. 9.

shown on a reduced scale in Fig. 9, with respect to which the following points are noteworthy:—

1. At distances beyond three metres the E.M.F. is everywhere parallel to the primary oscillation. Within this region, therefore, the electrostatic E.M.F. is negligible in comparison with the E.M.F. of induction. Now, all the theories of the mutual action of current elements agree in giving an E.M.F. of induction inversely proportional to the distance, while the electrostatic E.M.F., being due to the differential action of the two extremities of the primary, is approximately inversely proportional to the cube of the distance. Some of these theories, however, are not in accordance with the experimental result, that the effect diminishes much more rapidly in the direction of the primary oscillation than in a direction at right angles to it, induced sparks being observed at a distance exceeding 12 metres in the latter direction, while they disappeared at a distance of about four metres in the former direction.

2. That, as already proved, for distances less than one metre the distribution of E.M.F. is practically that of the electrostatic E.M.F.

3. There are two straight lines, at all points of which the direction of the E.M.F. is determinate, namely, the line in which the primary oscillation takes place, and the perpendicular to the primary through its middle point. Along the latter the E.M.F. does not vanish at any point, the sparking diminishes gradually as the distance is increased. This, again, is inconsistent with some of the theories of mutual action of current elements, according to which it should vanish at a certain definite distance. A very important result of the investigation is the demonstration of the existence of regions within which the direction of the E.M.F. becomes indeterminate. These regions form two rings encircling the primary circuit. Since the E.M.F. within them acts very nearly equally in every direction, it must assume different directions in succession, for, of course, it cannot act in different directions simultaneously.

The observations, therefore, lead to the conclusion that within these regions the magnitude of the E.M.F. remains very nearly constant, while its direction varies through all the points of the compass at each oscillation. Dr. Hertz states that he has been unable to explain this result, as also the existence of overtones, by means of the simplified theory in which the higher terms of the expansion of F are neglected, and he considers that no theory of simple action at a distance is capable of explaining it. If, however, the electrostatic E.M.F. and the E.M.F. of induction are propagated through space with unequal velocities, it admits of very simple explanation. For within these annular regions the two E.M.F.'s are at right angles and of the same order of magnitude; they will therefore, in consequence of the distance traversed, differ in phase, and the direction of the resultant will turn through all the points of the compass at each oscillation.

This phenomenon appears to him to be the first indication which has been observed of a finite rate of propagation through space of electrical actions, for if there is a difference in the rate of propagation of the electrostatic and electrodynamic E.M.F., one at least of them must be finite.

At the end of the Paper in which the preceding experiments are described Dr. Hertz describes some observations which he has made on the conditions at the primary sparking point which affect the production of sparks in the secondary circuit. He finds that illuminating the primary spark diminishes its power of exciting rapid oscillations, the sparks in the secondary being observed to cease when a piece of magnesium wire was burnt, or an arc lamp lighted, near the primary sparking point. The observed effect on the primary sparks is that they are no longer accompanied by a sharp crackling sound as before. The effect of a second discharge is especially noteworthy, and it was found that the secondary sparks could be made to disappear by bringing an insulated conductor close to the opposed surfaces of the spheres forming the terminals at the primary air space, even when no visible sparking took place between the latter and the insulated conductor. The secondary sparking could also be stopped by placing a fine point close to the primary air space, or by touching one of the opposed surfaces of the terminals with a piece of sealing-wax, glass, or mica. Dr. Hertz states that further experiments have led him to conclude that, even in these cases, the effect is due to light too feeble to be perceived by the eye, arising from a side discharge. He points out that these effects afford another example of the effects of light on electric discharges, which have been observed by E. Wiedemann, H. Ebert, and W. Hallwachs.

(To be continued.)

ALUMINIUM AND ALUMINIUM ALLOYS.*

The Swiss Metallurgical Society in Lauffen-Neuhausen, Canton Schaffhausen, has succeeded in producing aluminium alloys in large quantities by means of Hérault's method. In this method the electric current is employed for fusing refractory earths containing aluminium. The negative electrode is composed of the metal, copper, iron, or Mn, with which it is desired to alloy the aluminium; the positive electrode is composed of a group of carbons dipping into the molten argillaceous earth. The current is generated at these works by means of a vertical 300 horse-power Jonval turbine (Fig. 1) driving two dynamos of 6,000 amperes and 20 volts each, which are excited by a smaller Erreger

* Abstracted from the *Schweizerische Bauzeitung*, 4th August, 1888.

fundamental vibration of the secondary, since it is symmetrical on opposite sides of the air space.

The term $B \cos \frac{2\pi s}{S}$ will give a force acting in the same direction in the two quadrants opposed to the air space, and will excite the fundamental vibration. In the two quadrants adjacent to the air space it will give a force in the opposite direction, but its effect will be less than that of the former one. For the current is zero at the extremities of the circuit, and therefore the electricity cannot move so freely as near the centre. This corresponds to the fact that if a string fastened at each end has its central portion and ends acted on respectively by oppositely directed forces, its motion will be that due to the force at the central portion, which will excite the fundamental vibration if its oscillations are in unison with the latter. The intensity of the vibration will be proportional to B. Let E be the total E.M.F. in the uniform field of the secondary, ϕ the angle between its direction and the plane of the latter, and θ the angle which its projection on this plane makes with the radius drawn to the air space. Then we shall have approximately

$$F = E \cos\phi \sin\left(\frac{2\pi s}{S} + \theta\right),$$

and, therefore, $B = E \cos\phi \sin\theta.$

B, therefore, is a function simply of the total E.M.F. due both to the electrostatic and electro-dynamic actions. It will vanish when $\phi = 90°$—that is to say, when the total E.M.F. is perpendicular to the plane of the circle, whatever be the position of the air space on the circle. B will also vanish when $\theta = 0$—that is to say, when the projection of the E.M.F. on the plane of the circle coincides with the radius through the air space. If the position of the air space on the circle is varied, the angle θ will vary, and, therefore, also the intensity of the vibration and the sparking distance. The sparking distance corresponding to the second term of the expansion for F can, therefore, be represented approximately by a formula of the form $\beta \sin\theta$.

Now the oscillations giving rise to sparks of lengths α and $\beta \sin\theta$ respectively are in the same phase. The resulting oscillations will therefore be in the same phase, and their amplitudes must be added together. The sparking distance being approximately proportional to the maximum total amplitude may therefore also be obtained by adding the sparking distances due to the two oscillations respectively. The sparking distance will therefore be given as a function of the position of the air space on the secondary circuit by the expression $\alpha + \beta \sin\theta$. Since the direction of the oscillation in the air space does not come into consideration we are concerned only with the absolute value of this expression, and not with its sign. The determination of the absolute values of the quantities α and β would involve elaborate theoretical investigations, and is, moreover, unnecessary for the explanation of the experimental results.

Experiments with the Secondary Circuit in a Vertical Plane.—When the circle forming the secondary circuit was placed with its plane vertical, anywhere in the neighbourhood of the primary, the following results were obtained:—

The sparks disappeared for two positions of the air space, separated by 180°, namely, those in which it lay in the horizontal plane through the primary, but in every other position sparks of greater or less length were observed.

From this it followed that the value of α must have been constantly *zero*, and that θ was *zero* when the air space was in the horizontal plane through the primary.

The electro-magnetic lines of force must therefore have been perpendicular to this horizontal plane, and therefore consisted of circles with their centres on the primary, while the electrostatic lines of force must have been entirely in the horizontal plane, and therefore this system of lines of force consisted of curves lying in planes passing through the primary. Both of these results are in agreement with theory.

When the air space was at its greatest distance from the plane the sparking distance attained a maximum value of from 2 to 3 millimetres. The sparks were shown to be due to the fundamental vibration, by slightly varying the secondary, so as to throw it out of unison with the primary, when the sparking distance was diminished, which would not have been the case if the sparks had been due to overtones. Moreover, the sparks disappeared when the secondary was cut at its points of intersection with the horizontal plane through the primary, though these would be nodal points for the first overtone.

When the air space was kept at its greatest possible distance from the horizontal plane through the primary, and turned about a vertical axis, the sparking distance attained two maxima at the points for which $\phi = 0$, and almost disappeared at the points for which $\phi = 90°$.

The lower half of Fig. 8 shows the different positions of minimum sparking. A A' is the primary conductor, and the lines a a represent the projections of the secondary circuit on the horizontal plane. The arrows perpendicular to these give the direction of the resultant lines of force. As this did not anywhere vanish in passing from the sphere A to the sphere A', it could not change its sign.

The diagram brings out the two following points:—

(1) The distribution of the resultant E.M.F. in the vicinity of the rectilinear vibration is very similar to that of the electrostatic E.M.F. due to the action of its two extremities. It should be specially noted that near the centre of the primary the direction is that of the electrostatic E.M.F., showing that it is more powerful than the electrodynamic, as required by theory.

(2) The lines of force deviate more rapidly from the line A A' than the electrostatic lines, though this is not so evident

Fig. 8.

on the reduced scale of the diagram as in the author's original drawings on a much larger scale.

It is due to the components of the electrostatic E.M.F. parallel to A A' being weakened by the E.M.F. of induction, while the perpendicular components remain unaffected.

Experiments with the Secondary Circuit in a Horizontal Plane.—The results obtained when the plane of the secondary was horizontal can best be explained by reference to the upper half of the diagram in Fig. 8.

In the position I., with the centre of the circle in the line A A' produced, the sparks disappeared when the air space occupied either of the positions b_1 or b'_1, while two equal maxima of the sparking distance were obtained at a_1 and a'_1, the length of the spark in these positions being 2.5 millimetres. Both these results are in accordance with theory.

In the position II. the circle is cut by the electro-magnetic lines of force, and, therefore, α does not vanish. It will, however, be small, and we should expect that the expression $\alpha + \beta \sin\theta$ would have two unequal maxima $\beta + \alpha$ and $\beta - \alpha$, both for $\theta = 90°$, and having the line joining them perpendicular to the resultant E.M.F., and between these two maxima we should expect two points of no sparking near to the smaller maximum. This was confirmed by the observations.

The maximum sparking distances were 3.5 millimetres at a_2 and 2 millimetres at a'_2. Now with the air space at a_2, the sphere A being positive, the resultant E.M.F. in the opposite portion of the circle will repel positive electricity from A, and therefore tend to make it flow round the circle clockwise. Between the two spheres the electrostatic E.M.F. acts from A

towards A, and the opposite E.M.F. of induction in the neighbourhood of the primary acts from A to A, parallel to the former, and acting more strongly on the nearer than on the further portion of the secondary, tends to cause a current in the same direction as that due to the former, namely, in a clockwise direction. Thus the resultant E.M.F. is the sum of the two as required by theory, and in the same way it is easily seen that when the air space is at a'_2 the resultant E.M.F. is equal to their difference.

As the position III. is gradually approached, the maximum disappears, and the single maximum sparking distance a was found to be 4 millimetres in length, having opposite to it a point of disappearance a. In this case clearly $a = \beta$, and the sparking distance is given by the expression $a(1 + \sin\theta)$. The line $a_3 a$ is again perpendicular to the resultant E.M.F.

As the circle approaches further towards the centre of A A a will become greater than β, and the expression $a + \beta\sin\theta$ will not vanish for any value of θ, but will have a maximum $a + \beta$ and a minimum $a - \beta$, and in the experiments it was found that the sparks never entirely disappeared, but varied between a maximum and a minimum, as indicated by theory.

In the position IV. a maximum sparking distance of 5·5 millimetres was observed at a_4 and a minimum of 1·5 millimetre at a'_4.

In the position V. there was a maximum sparking distance of 6 millimetres at a and a minimum of 2·5 millimetres at a'. In these experiments the air space should be screened off from the primary in the latter positions as well as in the earlier ones, in which it is unavoidable, as otherwise the results would not be comparable.

In passing from the position III. to the position V. the line $a a$ rapidly turned from its position of parallelism to the primary current into a position perpendicular to it. In the latter positions the sparking was essentially due to the inductive action, and therefore the author was justified, in the experiments described in my previous Papers, in assuming the effect in these positions to be due to induction.

Even in these positions, however, the sparking is not totally independent of electrostatic action, except when the air space is half way between the maximum and minimum positions, and therefore $\beta \sin\theta = 0$.

(*To be continued.*)

THE USE OF ELECTRIC MOTORS ON SHIPBOARD.*

BY [illegible], U.S.N.

The use of electric motors is extending very rapidly ashore, and naturally raises the question whether there is a field for them on shipboard. The transmission of energy by electricity possesses two general advantages over any other system in being more economical when energy is to be transmitted to a distance, or when it is to be subdivided into a number of paths. The former has no application on shipboard, where distances are short, but the latter meets [illegible] many of the conditions for the modern navy.

A good dynamo will place 90 per cent. of the mechanical energy it receives in the form of available electrical energy in its external circuits. If now a good motor be placed in this circuit 90 per cent. of this electrical energy, or about 80 per cent. of the work of the engine, can be obtained as mechanical work. The loss in transmission is 20 per cent., and the cost of dynamo and motor renders such a system uneconomical in comparison with the simple one of placing a steam engine where the work is to be done. If, however, the power is required in twenty places instead of in one, the question becomes radically different, and this is the one inviting our attention.

In the new cruisers one of the first impressions received is that of complexity and confusion arising from the number of small engines scattered over the vessels. Nor is the feeling dispelled by a closer examination, for the ship is found to be a labyrinth of steam, exhaust, and circulating pipes, complex in arrangement, and requiring constant care and attention to keep in order. Joints and valves leak, steam condenses, and water freezes, totally disabling some part of the mechanism. If injuries occur, repairs are difficult and frequently impossible with the ship's resources, and an important engine may be disabled for months, or until the arrival of the vessel in port. A still more important objection to this complicated system of steam circulation in men of war is found in its liability to injury in action, and the danger to the crew which such injury might bring about. A single pipe cut by shot might disable a very important part of the ship's offensive apparatus, and pipes so injured are difficult to repair, and require time which could not be spared. The escape of steam in such a case would inevitably interfere with the fighting of the ship, and might cause loss of life or even a panic in the crew. If, therefore, it is necessary to use so many auxiliary motors, is steam the best vehicle for the transmission of power?

The electric motor is for equal power smaller than almost any steam engine, is more efficient, involves less waste in transmission, and has small mains, which are therefore less liable to injury, and admit of rapid repair of injuries. With the low potential used on shipboard there is, moreover, no danger to the personnel, and a broken main could be stopped without the delay of turning off the current. Every objection against the indiscriminate use of steam engines is removed by the use of the electric motor. A motor is, moreover, portable, and power may thus be quickly obtained at any place in the ship where the motor may be fastened down.

On grounds of utility, therefore, the motor appears to possess decided advantages. These appear to exist equally in economy. Small engines are notoriously uneconomical as compared with large ones. Small motors and dynamos are less so. By concentrating the whole auxiliary power of the ship in the dynamo room, large economical compound condensing engines may be used in driving high efficiency dynamos, and the power thus obtained distributed through large mains to the motors with very slight loss. The question of economy therefore rests upon the amount of subdivision, and is apparently in favour of the electric motor under just the circumstances in which distribution by steam becomes complex, and the loss due to using a number of uneconomical engines forms a large total aggregate. The question of economy of coal is one of the most important to be faced, and becomes paramount in a ship, which, without plenty of coal in her bunkers, is a mere helpless steel box, drifting at sea. Is it not advisable to seriously consider the saving and general advantages to be obtained by the high economy of large engines of the best type, and the high efficiency of well-designed dynamos and motors, in place of the notorious wastefulness, heat, dirt, and noise of small auxiliary engines?

In order to carry out such a plan it is only necessary to connect the motors to the incandescent light mains. It will be necessary to closely analyse the demands for power, and to place in the dynamo room a sufficient number of dynamos to supply the maximum required to be used at any time. The paramount consideration should be to have a reserve in action, and it is probable that more power will be needed then, through the use of gun carriage and other motors and search lights, than will be saved by the diminished use of incandescent lights. The dynamo room in this case becomes a central station for light and power, and valuable information may be derived from the experience of central stations ashore. It seems to be settled now in ordinary practice that, in cases where the load varies largely, it is in the long run more economical to use several engines of medium size, throwing in one after the other as the demand increases, rather than to employ one or two large engines which must generally be operated at partial load.

The objection to such a system is, that although the danger in action is not diffused over the whole ship it is concentrated in one place, and any injury there would cripple the ship. This is merely placing the dynamos in the same category as the engines and boilers, and, like them, the dynamo room must have all protection that can be given it. It should always be below the protective deck, when there is one, and in other cases below the water line. The mains should consist of several parts in parallel, connected together by copper wire spans at intervals. Each main becomes then a net work of conductors, and although this entails greater first cost, it reduces loss in transmission to a negligible quantity and guarantees safety and durability. The distribution should be made as much as possible below the protective deck, branch mains being generally vertical. Every circuit necessary in action should be thoroughly accessible for repairs, while at the same time receiving all possible protection. The highest insulation is of course demanded.

The simplicity of such a system is in marked contrast with that of steam distribution. All incandescent lights, search lights, and motors are connected in parallel, and any one may be put in or out of action by the movement of a single switch.

Apart from all advantages of distribution, the electric motor is the most efficient, compact, noiseless and simple vehicle for the transmission of energy that is known. If well made, it requires only ordinary care and attention to be always ready for use. Its principal danger on shipboard is from salt water, but with proper care this is small.

Nothing like a complete presentation of so wide a subject can be given within the limits of a single article, but the foregoing may call attention to some of the necessities of our service, and also to some fields in which experimental work may well be carried on.

* Extract from an official report to the United States Government.

of a flash being enormous, a very high difference of potential exists between every point of the conductor and the earth, however well the two are connected; hence the neighbourhood of a lightning conductor is always dangerous during a storm, and great circumspection must be exercised as to what metallic conductors are wittingly or unwittingly brought near or into contact with it. When a building is struck the oscillations and surgings all through its neighbourhood are so violent that every piece of metal is liable to give off sparks, and gas may be ignited even in neighbouring houses. If one end of a rain water gutter is attached to a struck lightning conductor the other end is almost certain to spit off a long spark, unless it also is metallically connected. Electric charges splash about in a struck mass of metal, as does the sea during an earthquake or when a mountain top drops into it.* Even a small spark near combustible substances is to be dreaded.

6. The electrical disturbance is conveyed to a conductor through the ether or space surrounding it, and so the more surface it exposes the better. Better than a single rod or tape is a number of separate lengths of wire, each thick enough not to be easily melted, and well separated so as not to interfere with each other by mutual induction.

The liability of rods to be melted by a flash can be easily overestimated. A rod usually fails by reason of its inertia or obstruction, and consequent inability to carry off the charge without spittings and side flashes; it very seldom fails by reason of being melted. In cases where a thin wire has got melted, the energy has been largely dissipated in the effort, and it has acted as an efficient protector, though, of course, for that time only. Large sectional area offers very little advantage over moderately small sectional area, such as No. 5 B.W.G.

7. Points, if numerous enough, serve a very useful purpose in neutralising the charge of a thunder cloud hovering over them, and thus often prevent a flash; but there are occasions, not imitated in the laboratory, when they are of no avail: for instance, when one upper cloud sparks into a lower one, which then suddenly overflows to earth. In the case of these sudden rushes, there is no time for a path to be prepared by induction, no time for points to exert any protective influence, and points then get struck by a violent flash just as if they were knobs. Discharges of this kind are the only ones likely to occur during a violent shower, because all leisurely effects would be neutralised by the raindrops better than by any multitude of points.

8. The path chosen by a galvanic current is no secure indication of the course which will be taken by a lightning flash. The course of a trickle down a hill side does not determine the path of an avalanche. Lightning will not select the easiest path alone; it can distribute itself among any number of possible paths, and can make paths for itself. Ordinary testing of conductors is therefore no guarantee of safety, and may be misleading. At the same time it is quite right to have some system of testing and of inspection, else rust and building alterations may render any protector useless.

9. There is no space near a rod which can be definitely styled an area of protection, for it is possible to receive violent sparks or shocks from the conductor itself. Not to speak of the innumerable secondary discharges which, by reason of electro-kinetic momentum and of induction and of the curious recently discovered effect of the ultra-violet light of a spark, are liable to occur as secondary effects in the wake of the main flash.

Just one word on the subject of iron *versus* copper. The writer last year thought and stated that, in so far as the substance of the conductor was magnetised by a discharge, iron would obstruct a lightning flash or any other rapidly varying current enormously more than copper does. But the fact is, that the substance of a conductor is, by sufficiently rapidly alternating currents, not magnetised at all. The current is tubular, keeps wholly to the outer surface, and magnetises nothing inside. Hence the magnetisability of the substance of the conductor is of no moment at all; and iron, therefore, will do every bit as well as copper. Mr. Preece's experience with half a million iron wire telegraph post protectors leads him to uphold iron as entirely satisfactory. So, on this one point, as well as on the necessity existing for a good earth, a portion of the practical and of the theoretical camps have been able to agree.

Immediately after the discussion Dr. [illegible] exhibited some preliminary attempts at photographs of lightning taken with a double-nozzled camera, having two sensitive plates, one fixed, the other revolving 30 times a second.* The same flash was depicted on both plates, but on the moving plate it was separated into two or three distinct streaks, showing its multiple character. Each constituent, however, was as clear and distinct on the rotating as on the fixed plate, and had in fact exactly the same shape and appearance, so that one could be superposed on the other exactly, thus proving its instantaneous character. The rate of spin was naturally nothing like sufficient to exhibit the alternating character of each constituent.

It is to be hoped that many more photographs of lightning will be taken on this plan, because there are evidently many kinds of composite flashes, and it is an excellent way of analysing them and correcting the impressions, often erroneous, formed by the eye.

On the whole, the Bath meeting, though not largely attended by the temporary class of members and associates, may be considered, so far as Section A is concerned, as one of the most interesting and important that have ever been held, thanks largely to the excellent arrangements made by the Secretaries; and the discoveries of Hertz, referred to by the President in his address, mark a distinct epoch in our acquaintance with electromagnetic phenomena.

* *Vide* The Eruption of Krakatoa, a pamphlet by E. Douglas Archibald, Tunbridge Wells; or the Report of the Krakatoa Committee.

* See a letter in *Nature*, July 12, 1888.

HERTZ'S RESEARCHES ON ELECTRICAL OSCILLATIONS.

BY G. W. DE TUNZELMANN, B.Sc.

(Continued from page [illegible].)

Nodes.—The vibrations in the micrometer circuit which have been considered are the simplest ones possible, but not the only ones. While the potential at the ends alternates between two fixed limits, that at the central portion of the circuit retains a constant mean value. The electrical vibration, therefore, has a node at the centre, and this will be the only nodal point. Its existence may be proved by placing a small insulated sphere close to various portions of the micrometer circuit while sparks are passing at the discharger of the coil, when it will be found that if the sphere is placed close to the centre of the circuit the sparking will be very slight, increasing as the sphere is moved further away. The sparking cannot, however, be entirely got rid of, and there is a better way of determining the existence and position of the node. After adjusting the two circuits to unison, and drawing the micrometer terminals so far apart that sparks can only be made to pass by means of resonant action, let different parts of the circuit be touched by a conductor of some capacity, when it will be found that the sparks disappear, owing to interference with the resonant action, except when the point of contact is at the centre of the circuit. The author then endeavoured to produce a vibration with two nodes, and for this purpose he modified the apparatus previously used by adding to the micrometer circuit a second rectangle [illegible] exactly similar to the first (as shown in Fig. [illegible]), and joining the points of the circuit near the terminals by wires [illegible] and [illegible], as shown in the diagram.

The whole system then formed a closed metallic circuit, the fundamental vibration of which would have two nodes. Since the period of this vibration would necessarily agree closely with that of each half of the circuit, and, therefore, with that of the circuit C C', it was to be expected that the vibration would have a pair of loops at the junctions 13 and 24,

and a pair of nodes at the middle points of cd and gh. The vibrations were determined by measuring the sparking distance between the micrometer terminals 1 and 2. It was found that, contrary to what was expected, the addition of the second rectangle diminished this sparking distance from about 3 millimetres to about 1 millimetre. The existence of resonant action between the circuit C C' and the micrometer circuit was, however, fully demonstrated, for any alteration in the circuit $efgh$, whether it consisted in increasing or in decreasing its length, diminished the sparking distance. It was also found that much weaker sparks took place between cd or gh and an insulated sphere, than between [illegible] and the same sphere, showing that the nodes were in cd and gh, as expected. Further, when the sphere was made to touch cd or gh it had no effect on the sparking distance of 1 and 2, but when the point of contact was at any other portion of the circuit the sparking distance was diminished, showing that these nodes did really belong to the vibration the resonant action of which increased this spark distance.

The wire joining the points 3 and 4 was then removed. As the strength of the induced oscillatory current should be zero at these points the removal ought not to disturb the vibrations, and this was shown experimentally to be the case, the resonant effect and the position of the nodes remaining unchanged. The vibration with two nodal points was, of course, not the fundamental vibration of the circuit, which consisted of a vibration with a node between [illegible] and [illegible], and for which the highest values of the potential were at the points 3 and 4.

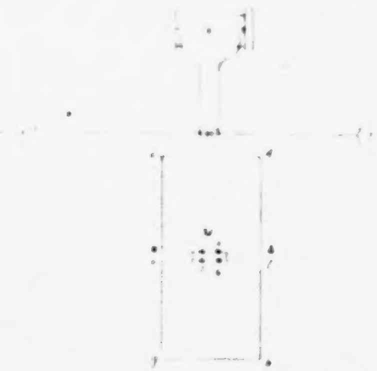


Fig. 7.

When the spheres forming the terminals at these points were brought close together slight sparking was found to take place between them, which was attributed to the excitation, though only to a small extent, of the fundamental vibration. This explanation was confirmed in the following manner. The sparks between 1 and 2 were broken off, leaving only the sparks between 3 and 4, which measured the intensity of the fundamental vibration. The period of vibration of the circuit C C' was then increased by drawing it out to its full length and thereby increasing its capacity, when it was observed that the sparking gradually increased to a maximum, and then began to diminish again. The maximum value must evidently occur when the period of vibration of the circuit C C' is the same as that of the fundamental vibration of the micrometer circuit, and it was shown that when the sparking distance between 3 and 4 had its maximum value, the sparks corresponded to a vibration with only one nodal point, for the sparks ceased when the previously existing nodes were touched by a conductor, and the only point where contact could take place without effect on the sparking was between [illegible] and [illegible]. These results show that it is possible to excite at will in the same conductor, either the fundamental vibration or its first overtone, to use the language of acoustics.

Hertz appears to consider it very doubtful whether it will be possible to get higher overtones of electrical vibration, the difficulty of obtaining such lying not only in the method of observation, but also in the nature of the oscillations themselves. The intensity of these is found to vary considerably during a series of discharges from the coil even when all the circumstances are maintained as constant as possible, and the comparative feebleness of the resonant effects shows that there must be a considerable amount of damping. There are, moreover, many secondary phenomena which seem to indicate that irregular vibrations are superposed upon the regular ones, as would be expected in complex systems of conductors. If, therefore, we wish to compare electrical oscillations, from a mathematical point of view, with those of acoustics, we must seek our analogy in the high notes intermixed with irregular vibrations, obtained, say, by striking a wooden rod with a hammer, rather than in the comparatively [illegible] harmonic vibration of tuning forks, or strings; and in the case of vibrations of the former class we have to be contented, even in the study of acoustics, with little more than indications of such phenomena as resonance and nodal points.

Referring to the conditions to be fulfilled in order to [illegible] the best results, should other physicists desire to repeat the experiments, Dr. Hertz notes a fact of very considerable interest and novelty, namely, that the spark from the discharger should always be visible from the micrometer, as when this was not the case, though the phenomena observed were of the same character, the sparking distance was invariably diminished. This effect of the light from the spark of an induction coil in increasing the sparking distance in the secondary circuit of another coil excited great interest when referred to by Prof. Lodge in the course of the recent discussion on Lightning Conductors at the British Association, and he pointed out that the same effect was produced by light from burning magnesium wire, or other sources rich in the ultra violet rays.

Theory of the Experiments.—The theories of electrical oscillations which have been developed by Sir William Thomson, von Helmholtz, and Kirchhoff have been shown* to hold good for the open circuit oscillations of induction apparatus, as well as for the oscillatory Leyden jar discharge, and, although Dr. Hertz has not succeeded in obtaining definite quantitative results to compare with theory, it is of interest to inquire whether the observed results are of the same order as those indicated by theory.

Hertz considers, in the first place, the vibration period. Let T be the period of a single or half vibration proper to the conductor exciting the micrometer circuit, P its coefficient of self-induction in absolute electromagnetic measure, expressed, therefore, in centimetres, C the capacity of one of its terminals in electrostatic measure and, therefore, also expressed in centimetres, and v the velocity of light in centimetres per second. Then, if the resistance of the conductor is small,

$$T = \frac{\pi\sqrt{PC}}{v}$$

In the case of the resonance experiments, the capacity C was approximately the radius of the sphere forming the terminal, so that C = 15 centimetres. The coefficient of self-induction was that of a wire of length l = 150 centimetres, and diameter d = 0·2 centimetre.

According to Neumann's formula

$$P = 2l\left(\log\frac{4l}{d} - 0.75\right)$$

which gives in the case considered

$$P = 2l\left(\log\frac{4l}{d} - 0.75\right) = 1902\text{cm}$$

As, however, it is not quite certain that Neumann's formula is applicable to an open circuit, it is better to use von Helmholtz's more general formula, containing an undetermined constant k, according to which

$$P = 2l\left(\log\frac{4l}{d} - 0.75 + \frac{1-k}{2}\right)$$

Putting k = 1 this reduces to Neumann's formula, for k = 0 it reduces to that of Maxwell, and for k = [illegible] to Weber's. The greatest difference in the values of P obtained by giving these different values to k would not exceed a sixth of its mean value, and, therefore, for the purposes of the present approx-

* Lorentz, Wiedemann's *Annalen*, Vol. VII., p. 161, 1879.

[illegible] it is enough to assume that [illegible] is not a large positive [illegible] number; for if the number [illegible] does not give [illegible] value of the coefficient for the wire [illegible] in length, it [illegible] give the value corresponding to a conductor not differing greatly from it in length.

Taking [illegible] we have [illegible] which represents the distance traversed by light during the oscillation, or, according to Maxwell's theory, the length of an electromagnetic ether wave. The value of T is then found to be [illegible] millionths of a second, which is of the same order as [illegible] observed results.

The ratio of damping is then considered. In order that oscillations may be possible the resistance of the open circuit [illegible] less than [illegible]. For the exciting circuit [illegible] ohms as the upper limit of resistance. If the actual resistance [illegible] is sensibly below this limit, the ratio of damping [illegible]. The amplitude will therefore be reduced in [illegible] ratio [illegible] in [illegible]

[illegible] We have unfortunately no means of determining [illegible] of the air space traversed by the spark, but as [illegible] of a strong electric arc is never less than a few [illegible] we shall be justified in assuming this as the minimum [illegible]. From this it would follow that the number of oscillations due to a single impulse must be reckoned in tens and [illegible] hundreds or thousands, which is in accordance with the [illegible] of the experimental results and agrees with the [illegible] observed in the case of the oscillatory Leyden jar discharge. In the case of closed metallic circuits on the other hand theory indicates that the number of oscillations before [illegible] is attained must be reckoned by thousands.

Hertz compares, lastly, the order of the inductive action of [illegible], according to theory, with that of the effects [illegible] observed. To do this it must be noted that the maximum E.M.F. induced by the oscillation in its own circuit is approximately equal to the maximum potential difference [illegible] if there were no damping these quantities would be [illegible] since at each moment the potential difference at the extremities and the E.M.F. of induction would be in equilibrium. In the experiments under consideration the potential difference at the extremities was such as to give a spark [illegible] mm. in length, which must therefore represent the maximum inductive action exerted in its own circuit by the oscillation. [illegible] at any instant the induced E.M.F. in the micrometer [illegible] must be to that in the exciting conductor in the same ratio as that of the coefficient of mutual induction [illegible] of the two circuits to the coefficient of self-induction P of the exciting circuit. The value of [illegible] for the case considered is easily calculated from the ordinary formulæ, and it is found to lie between one-tenth and one-twelfth of P. This would only give sparks of from [illegible] to [illegible] mm. in length, so that according to theory visible sparks ought in any case to be obtained; but, on the other hand, sparks several millimetres in length, as were obtained in the experiments previously described, can only be explained on the assumption that the successive inductive actions produce an accumulative effect; so that theory indicates the necessity of the existence of the resonant effects actually observed.

(To be continued.)

ON THE APPLICATION OF ELECTRICITY TO THE WORKING OF A 20-TON TRAVELLING CRANE.*

[illegible] travelling crane in the foundry [illegible] was originally constructed to be worked by hand [illegible] had been made for the application of [illegible] at some future time.

The crane is [illegible] span, and consists of a pair of wrought iron girders resting on end carriages, each running on two wheels on an elevated line of rails. The gearing for hoisting [illegible] and for cross traverse is secured on [illegible] the hoisting chain passes from the barrel [illegible] the crane over a pulley [illegible] cross traverse [illegible] thence through a [illegible] under the barrel at the extreme end of the main girders. By this arrangement the [illegible] height, and the hook can come within [illegible] of each wall.

The inconvenience and wear attending the use of rope driving [illegible] of a long main driving shaft, and the dirt and special attention required by a steam crane, induced the writer to try whether electricity might not be used with advantage. Messrs. Elwell-Parker, of Wolverhampton, were communicated with, and these gentlemen undertook to supply the dynamo and a motor suitable for the peculiar requirements of a heavy crane.

The dynamo, which is considerably larger than is needed for the crane in question, is arranged to give up to [illegible] amperes at [illegible] volts, with [illegible] revolutions per minute. The armature is of the cylinder type, field magnets shunt wound, resistance of armature [illegible] ohm and of the magnets [illegible] ohms. It is fixed in the main boiler house of the works, and is driven by a horizontal engine having a cylinder [illegible] stroke, running at [illegible] revolutions, with [illegible] by means of a link belt. The leads from the boiler house up to the conductors in the foundry, for a distance of [illegible], are of [illegible] copper wire, while the conductor in the foundry is formed of an angle iron [illegible] along the whole [illegible] length of the shop at [illegible] from the ground, and protected from [illegible] and [illegible] to the iron pillars supporting the [illegible] insulated by wood blocks. The return current travels [illegible] the rails on which the crane runs, the [illegible] of the rails being [illegible] by copper staples. The motor is of Messrs. Elwell-Parker's latest type, [illegible] drum armature, [illegible] shunt wound, and constructed for [illegible] volts and [illegible] amperes. The armature [illegible] ohm, that of the shunt [illegible] ohms. It is fixed on the working platform of the crane beside one of the main girders. Its driving spindle carries a steel pinion, which gears into a double helical spur wheel, keyed on to a shaft which runs longitudinally on the top of the girder, and is connected by [illegible] wheels, with friction clutch connections, to the three shafts which command the several movements of the crane, the means of using the hand power being still retained. Two sets of speed are arranged for each of the movements, namely:

	Slow [illegible]	Fast [illegible]
Hoisting	[illegible]	10ft.
Cross traverse	[illegible]	105 ,,
Longitudinal traverse	[illegible]	213 ,,

To provide against an undue current passing through the motor an automatic magnetic cut-out is fixed on the crane, and as an additional security a fusible wire is placed close to the dynamo to provide for the contingency of a short circuit. For the purpose of varying the power and speed to meet the requirements of the foundry, a set of resistance coils is provided, governed by a special switch, by means of which different resistances can be introduced into the armature circuit of the motor, and the current can be cut off altogether, but so that it must be done by steps, and not suddenly. In starting the motor the reverse action takes place. The shunt coils of the magnets are connected to the two collectors, so that the fields are always excited when the dynamo is running, whether the motor is working or not, the switch controlling only the armature circuit. The collector for the angle iron conductor consists of a pair of insulated brass blocks pressed against it by means of a flat spring having a considerable range. An ordinary wire brush serves to collect the current from the rail, but the axle of one of the wheels is also connected to this brush to provide for the contact being in any way interrupted.

The handles for operating the several movements, the brake lever, the switch, and the automatic cut-out are all collected

* [illegible] before the British Association at Bath [illegible] 1888.

of some electricity, either with or through a conductor. Now, whenever electricity moves, it at once has magnetic properties, its motion generates a magnetic field. When the motion ceases the field at once subsides, and in subsiding it may produce a succession of diffusing and dying away induction currents in neighbouring conductors, or it may, if the circuit be an incomplete one, leave a permanent vestige of itself in the dielectric as a field of strained ether this state of strain being what we call electrostatic potential, and the field being familiar to us as an electrostatic field.

Generating it in this way, all distinction between rate of propagation of electrostatic and electromagnetic potential vanishes, they both travel together with the velocity of light, or rather, the thing which travels is the magnetic potential, and its permanent effect *in situ* is the electrostatic potential.

Thus, once more, the difficulty of a longitudinal or pressural wave disappears from the electrical theory of light, into which it had seemed to intrude itself, and Ψ is left to enjoy "a long and useful career," though it is not permitted an infinite or any other rate of propagation in its own proper nature. The question of the incompressibility or compressibility of the ether thus remains unanswered, and, as it would seem, unanswerable, by any such experiments as those of Hertz, or by any experiments on the rate of transmission of electrostatic potential. If any one asks how soon will the pull of a suddenly electrified body be felt at a distance? one may answer, "As soon as the charging spark is seen." But if it be asked at what rate electrostatic potential travels, the answer is that it does not travel, but is generated *in situ* by the subsidence of a magnetic potential which travels with the velocity of light.

It must be understood that the last word has by no means been said on these great problems, and that what I have here written must be digested with salt. It is proper also to record the conviction expressed by the President that most of these refined points would probably be found mathematically treated somewhere in the writings of Mr. Heaviside.

(To be continued.)

HERTZ'S RESEARCHES ON ELECTRICAL OSCILLATIONS.

BY G. W. DE TUNZELMANN, B.SC.

(Continued from page 589.)

In a note in Wiedemann's *Annalen*, Vol. XXXI., page 545, Dr. Hertz states that since the publication of his Paper in the same volume, he had found that von Bezold had published a Paper in 1870 (Poggendorff's *Annalen*, Vol. CXL., page 541), in which he had arrived by a different method of experimenting at similar results and conclusions as those given by him under the head of Preliminary Experiments.

Induction Phenomena in Open Circuits.—In order to test more fully his conclusion that the sparks obtained in the experiments described in my last Paper were due to self-induction, Dr. Hertz placed a rectangle of copper wire with sides 10 and 20 centimetres in length respectively, broken by a short air space, with one of its sides parallel and close to various portions of the secondary circuit of the coil, and of the micrometer circuit, with solid dielectrics interposed, to obviate the possibility of sparking across, and he found that sparking in this rectangle invariably accompanied the discharges of the induction coil, the longest sparks being obtained when a side of the rectangle was close to the discharger.

A copper wire, *i g h* (Fig. 3), was next attached to the discharger, and a side of the micrometer circuit, which was supported on an insulating stand, was placed parallel to a portion of this wire, as shown in the diagram. The sparks at M were then found to be extremely feeble until a conductor, C, was attached to the free end, *h*, of the copper wire, when they increased to one or two millimetres in length. That the action of C was not an electrostatic one was shown by its producing no effect when attached at *g* instead of at *h*. When the knobs of the discharger B were so far separated that no sparking took place there, the sparks at M were also found to disappear, showing that these were due to the sudden discharges and not to the charging current. The sparks at the discharger which produced the most effect at the micrometer were of the same character as those described in my last Paper. Sparks were also found to occur between the micrometer circuit and insulated conductors in its vicinity. The sparks became much shorter when conductors of larger capacity were attached to the micrometer knobs, or when these were touched by the hand, showing that the quantity of electricity in motion was too small to charge these conductors to a similarly high potential. Joining the micrometer knobs by a wet thread did not perceptibly diminish the strength of the sparks. The effects in the micrometer circuit were not of sufficient strength to produce any sensation when it was touched or the circuit completed through the body.

In order to obtain further confirmation of the oscillatory nature of the current in the circuit *k i h g* (Fig. 3), the conductor C was again attached to *h*, and the micrometer knobs drawn apart until sparks only passed singly. A second conductor, C′, as nearly as possible similar to C, was then attached to *k*, when a stream of sparks was immediately observed, and it

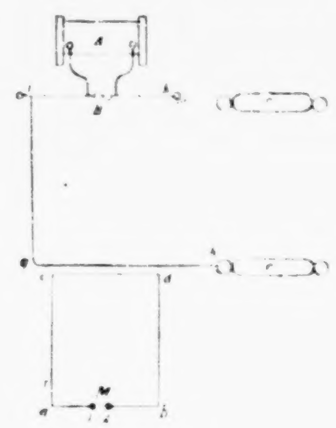


Fig. 3.

continued when the knobs were drawn still further apart. This effect could not be ascribed to a direct action of the portion of circuit *i k*, for in this case the action of the portion of circuit *g h* would be weakened, and it must therefore have consisted in C′ acting on the discharging current of C, a result which would be quite incomprehensible unless the current in *g h* were of an oscillatory character.

Since an oscillatory motion between C and C′ is essential for the production of powerful inductive effects, it will not be sufficient for the spark to occur in an exceedingly short time, but the resistance must at the same time not exceed certain limits. The inductive effects will therefore be excessively small if the induction coil included in the circuit C C′ is replaced by an electrical machine alternately charging and discharging itself, or if too small an induction coil is used; or, again, if the air space between the discharger knobs is too great, as in all these cases the motion ceases to be oscillatory.

The reason that the discharges of a powerful induction coil gives rise to oscillatory motion is that, firstly, it charges the terminals C and C′ to a high potential; secondly, it produces a sudden spark in the intervening circuit; and, thirdly, as soon as the discharge begins the resistance of the air space is so much reduced as to allow of oscillatory motion being set up. If the terminal conductors are of very large capacity, for example, if the terminals are in connection with a battery, the current of discharge may indefinitely reduce the resistance of the air space, but when the terminal conductors are of small capacity this must be done by a separate discharge, and there-

fore, under the conditions of the author's experiments, an induction coil was absolutely essential for the production of the oscillations.

As the induced sparks in the experiment last described were several millimetres in length, the author modified it by using the arrangement shown in Fig. 4, and greatly increasing the distance between the micrometer circuit and the secondary circuit of the induction coil. The terminal conductors C and C' were three metres apart, and the wire between them was of copper, 2 millimetres in diameter, with the discharger B at its centre.

The micrometer circuit consisted, as in the preceding experiments, of a rectangle 80 centimetres broad by 120 centimetres long. With the nearest side of the micrometer circuit at a distance of half a millimetre from C B C' sparks two millimetres in length were obtained at M, and though the length of the sparks decreased rapidly as the distance of the micrometer circuit was increased, a continuous stream of sparks was still obtained at a distance of one and a half metres. The intervention of the observer's body between the micrometer circuit and the wire C B C' produced no visible effect on the stream of sparks at M. That the effect was really due to the rectilinear conductor C B C' was proved by the fact that when one or other, or both halves of this conductor were removed, the sparks at M ceased. The same effect was produced by drawing the knobs of the discharger B apart until sparks ceased to pass, showing that the effect was not due to the electrostatic potential difference of C and C', as this would be increased by separating the discharger knobs beyond sparking distance.

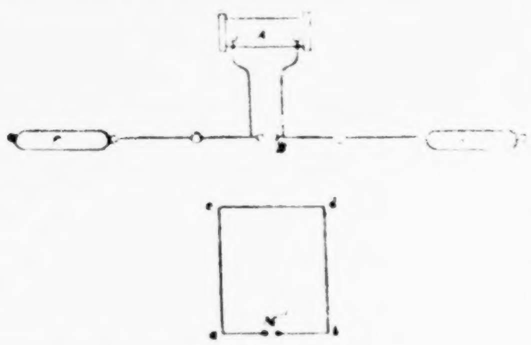


FIG. 4.

The closed micrometer circuit was then replaced by a straight copper wire, slightly shorter than the distance C C', placed parallel to C B C', and at a distance of 60 centimetres from it. This wire terminated in knobs, 10 centimetres in diameter, attached to insulating supports, and the spark micrometer divided it into two equal parts. Under these circumstances, sparks were obtained at the micrometer, as before.

With the rectilinear open micrometer circuit sparks were still observed at the micrometer when the discharger knobs of the secondary coil circuit were separated beyond sparking distance. This was, of course, due simply to electrostatic induction, and shows that the oscillatory current in C C' was superposed upon the ordinary discharges. The electrostatic action could be got rid of by joining the micrometer knobs by means of a damp thread. The conductivity of this thread was therefore sufficient to afford a passage to the comparatively slow alternations of the coil discharge, but was not sufficient to provide a passage for the immeasureably more rapid alternations of the oscillatory current. Considerable sparking took place at the micrometer when its distance from C B C' was 1.2 metres, and faint sparks were distinguishable up to 3 metres. At these distances it was not necessary to use the damp thread to get rid of the electrostatic action, as, owing to its diminishing more rapidly with increase of distance than the effect of the current induction, it was no longer able to produce sparks in the micrometer, as was proved by separating the discharger knobs beyond speaking distance, when sparks could no longer be perceived at the micrometer.

Resonance Phenomena.—In order to determine whether, as some minor phenomena had led the author to suppose, the oscillations were of the nature of a regular vibration, he availed himself of the principle of resonance. According to this principle, an oscillatory current of definite period would, other conditions being the same, exert a much greater inductive effect upon one of equal period than upon one differing even slightly from it.*

If, then, two circuits are taken having as nearly as possible equal vibration periods, the effect of one upon the other will be diminished by altering either the capacity or the coefficient of self-induction of one of them, as a change in either of them would alter the period of vibration of the circuit.

This was carried out by means of an arrangement very similar to that of Fig. 4. The conductor C C' was replaced by a straight copper wire 2.6 metres in length and 5 millimetres in diameter, divided into two equal parts as before by a discharger. The discharger knobs were attached directly to the secondary terminals of the induction coil. Two hollow zinc spheres, 30 centimetres in diameter, were made to slide on the wire, one on each side of the discharger, and since, electrically speaking, these formed the terminals of the conductor, its length could be varied by altering their position. The micrometer circuit was chosen of such dimensions as to have, if the author's hypothesis were correct, a slightly shorter vibration period than that of C C'. It was formed of a square, with sides 75 centimetres in length, of copper wire 2 millimetres in diameter, and it was placed with its nearest side parallel to C B C', and at a distance of 30 centimetres from it. The sparking distance at the micrometer was then found to be 0.9 millimetre. When the terminals of the micrometer circuit were placed in contact with two metal spheres 8 centimetres in diameter, supported on insulating stands, the sparking distance could be increased up to 2.5 millimetres. When these were replaced by much larger spheres the sparking distance was diminished to a small fraction of a millimetre. Similar results were obtained on connecting the micrometer terminals with the plates of a Kohlrausch condenser. When the plates were far apart the increase of capacity increased the sparking distance, but when the plates were brought close together the sparking distances again fell to a very small value.

The simplest method of adjusting the capacity of the micrometer circuit is to suspend to its ends two parallel wires, the distance and lengths of which are capable of variation. By this means the author succeeded in increasing the sparking distance up to three millimetres, after which it diminished when the wires were either lengthened or shortened. The decrease of the sparking distance on increasing the capacity was naturally to be expected, but it would be difficult to understand, except on the principle of resonance, why a decrease of the capacity should have the same effect.

The experiments were then varied by diminishing the capacity of the circuit C B C', so as to shorten its period of oscillation, and the results confirmed those previously obtained, and a series of experiments in which the lengths and capacities of the circuits were varied in different ways, showed conclusively that the maximum effect does not depend on the conditions of either one of the two circuits, but on the existence of the proper relation between them.

When the two circuits were brought very close together and the discharger knobs separated by an interval of 7 millimetres, sparks were obtained at the micrometer, which were also 7 millimetres in length, when the two circuits had been carefully adjusted to have the same period. The induced E.M.F.s must in this case have attained nearly as high a value as the inducing ones.

To show the effect of varying the coefficient of self-induction, a series of rectangles, *a b c d* (Fig. 4), were taken, having a constant breadth, *a b*, but a length, *a c*, continually increasing from 10 centimetres up to 250 centimetres. It was found that the maximum effect was obtained with a length of 1.8 metres. The quantitative results of these experiments are shown in Fig. 5, in which the abscissæ of the curve are the double lengths of the rectangles, and the ordinates represent the corre-

* See Oberbeck, Wiedemann's *Annalen*, Vol. XXVI., p. 245, 1885.

sponding maximum sparking distances. The sparking distances could not be determined with great exactness, but the errors were not sufficient to mask the general nature of the result.

In a second series of experiments the sides *a c* and *b d* were formed of loose coils of wire which were gradually pulled out, and the result is shown in Fig. 6. It will be seen that the maximum sparking distance was attained for a somewhat greater length of side, which is explained by the fact that in the latter experiments the self induction only was increased by increase of length, while in the former series the capacity was increased as well. Varying the resistance of the micrometer circuit by using copper and German silver wires of various diameters was found to have no effect on the period of oscillation, and extremely little on the sparking distance.

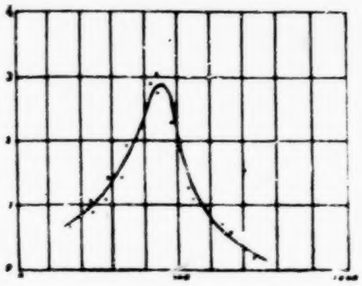


FIG. 5.

Curve showing relation between length of side of rectangle (taken as abscissa) and maximum sparking distance (taken as ordinate), the sides consisting of straight wires of varying lengths.

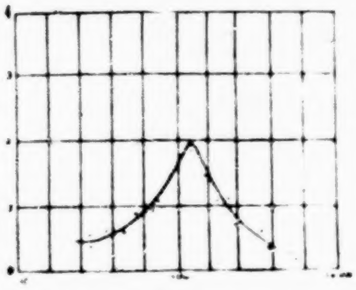


FIG. 6.

Curve showing relation between length of side of rectangle (taken as abscissa) and maximum sparking distance (taken as ordinate), the sides consisting of spirals gradually drawn out.

When the wire *c d* was surrounded by an iron tube, or when it was replaced by an iron wire, no perceptible effect was obtained, confirming the conclusion previously arrived at that the magnetism of the iron is unable to follow such rapid oscillations, and therefore exerts no appreciable effect.

(To be continued.)

DYNAMOS WITHOUT COMMUTATORS OR BRUSHES.

BY TH. MARCHER (OF MULHEIM).

The first recorded attempt to construct a continuous-current dynamo without the impediments of commutator and brushes is due to M. A. F. Gravier, who took out a patent in France for a dynamo of this class. In 1882 a Mr. E. Newton obtained a similar patent in England. In 1883 L. Hajnis, of Prague, took out a patent in Germany for a dynamo on this principle; but in which some of the defects of the Gravier machine were avoided. In 1887 the Cronstadt Electrical Manufacturing Company also designed a dynamo without commutators. Since then but little seems to have been done in this direction.

I will, in the first place, briefly describe the original Gravier machine, from which he subsequently developed the non-commutator type. In Fig. 1 N and S are the field magnets; *a a a* and *b b b* are the armature coils, which are mounted on radial cores, as in the Lontin type; and $+f$ and $-f$ are the brushes. When the armature revolves in the direction shown by the large arrow currents are induced in the coils in the direction shown by the small arrows. The armature poles *a a a*, therefore, become S magnetised, and the poles *b b b* N magnetised. Now imagine a second armature of the ring type, interposed between the above mentioned armature and the poles N S, this second armature having no coils at A' A' and B' B' (Fig. 2). The magnets *a a a* will produce in this armature a current flowing in the direction *c s*, and the magnets

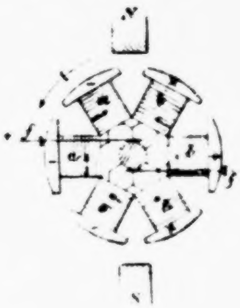


FIG. 1.

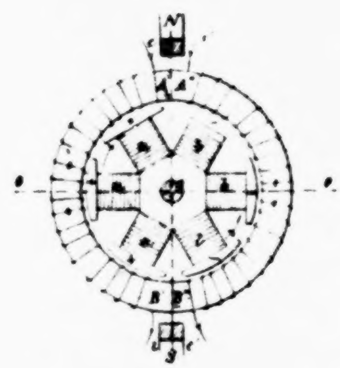


FIG. 2.

b b b will produce a current flowing in the reverse direction, *i.e.* Now, these two currents induce poles at A' A' and B' B' similar to those of the field-magnets, N S, at the adjacent points. If, therefore, sufficient residual magnetism was present, the magnet N S could be dispensed with, and the pole A' A' and B' B' would suffice. Gravier, however, was unable to get any good results from this form of machine, and subsequently designed one without commutator, collector, or brushes. In this dynamo (Fig. 3) Gravier had a revolving armature *i*, a revolving system of magnetisation, N S, a fixed armature I I, and a fixed system of magnetisation *s s*. The theoretical outcome of this arrangement is as follows:—The magnets *s s* induce currents in *i*, which excite the magnets N S, which in turn induce currents in I I; the current thus obtained passes into the external circuit, and also round the magnets *s s*. One method of winding is shown in Fig. 4. The Hajnis machine consists of the same four essential parts, namely, fixed armature and field-magnets, and revolving armature and field magnets, the revolving parts being mounted on the same shaft. This arrangement is shown diagrammatically in Fig. 5. M M M M are fixed magnets, A A are revolving armature coils, B B B B are revolving magnets, and P P is the fixed ring armature. From each individual coil of the revolving armature connections are made to the corresponding magnet coil, each armature coil being one behind the

[illegible] to the *static hysteresis* experiments by Prof. Ewing and others also indicate the existence of *viscous* [illegible]. There is evidence of a true *time lag* in magnetisation, especially in the earlier stages of magnetisation. The iron requires time for a given magnetising force to produce [illegible] effect, and this sluggishness does not appear explicable as [illegible] either of induction in the iron or to self-induction in the magnetising circuit. The result of this magnetic viscosity is to augment the value of $-\int I\,dH$ in any rapidly performed cycle, and, consequently, to increase the dissipation of energy [illegible]. When we come to consider the question of induction transformers it will be seen that this viscous hysteresis has to be taken into account in establishing the full theory.

With respect to this *time lag* of magnetisation Prof. Ewing says:* "I repeatedly observed that when the magnetising current was applied to long wires of soft iron there was a distinct *creeping up* of the magnetometer deflection after the current had attained a steady value."†

If this is so it would seem that a sufficiently rapid reversal of magnetising force would render such force inoperative in magnetising the iron. Just as the self-induction of a circuit operates to make a certain delay in the appearance of the current corresponding to the application of a given electromotive force, and hence renders a circuit apparently a worse conductor for rapidly reversed electromotive forces, so the magnetic lag would introduce a sort of *magnetic self-induction* or retardation in the appearance of the magnetisation corresponding to a given magnetising force.

This time lag appears to be most manifest in the softest iron, and to be especially noticeable near the beginning of the steep part of the magnetisation curve.

In an investigation on the magnetisation of iron under feeble magnetic forces, Lord Rayleigh has also drawn attention to the fact that the settling down of iron when very soft or annealed [illegible] into a new magnetic state is far from instantaneous;‡ if the strength of the earth's horizontal magnetic field is called h, Lord Rayleigh has shown that for unannealed iron and steel magnetising forces ranging from $\frac{1}{2}h$ to $\frac{1}{10000}h$ call forth proportional magnetisation. In other words, the susceptibility is constant over this range, and the value of the corresponding permeability is from 90 to 100, and that this small proportional magnetisation takes place independently of what may be the actual magnetisation of the iron provided it is not very near the condition usually called saturation.

The moment, however, that the magnetising force is pushed beyond these limits the phenomena of hysteresis and retentiveness make their appearance. According to Prof. Ewing (*loc. cit.*) the following group or constellation of hypotheses has to be made in order to approximate to a mechanical explanation of the magnetisation of iron:

1. An elastic tendency on the part of the magnetic molecules to recover their primitive position when displaced.

2. A static frictional resistance to their displacement and to their return removable largely by vibration.

3. A limit for each such that if the displacement of the molecule exceeds it a permanent displacement not removable by vibration results.

4. Probably a viscous resistance to the displacement and return of the molecules.

5. An unequal distribution amongst the molecules of the frictional resistance, such that in some of the molecules it is, perhaps, very small.

Aided by these suppositions we might proceed to build up, in imagination, a mechanical model, which should imitate, under the application of certain stresses, the behaviour of iron under magnetising force, but it is certain that the result would not be practically of much value; and it must still be left to future research to collect and analyse the necessary facts before the mystery of the magnetisation of iron is fully unraveled.

* *Phil. Trans.*, Part II., 1885, p. 569.

† See also Mr. T. Blakesley "On Magnetic Lag," *Phil. Mag.*, July, 1888, p. 34, in which it is shown that, by means of three dynamometers, the lag due to viscous hysteresis may be measured.

‡ Lord Rayleigh "On the Behaviour of Iron and Steel under the Operation of Feeble Magnetic Forces," *Phil. Mag.*, March, 1887, p. 225.

HERTZ'S RESEARCHES ON ELECTRICAL OSCILLATIONS.

BY G. W. DE TUNZELMANN, B.Sc.

H. Hertz has been engaged for some time past in a series of researches on electrical oscillations, which have led to results of very exceptional interest, as was pointed out by Prof. Fitzgerald in his inaugural address to Section A of the British Association last week; and as these results throw considerable light on the nature of electrical action, it will be of interest to readers of *The Electrician* to have a connected account of the investigations, to which I therefore propose to devote a short series of papers.

In Hertz's first Paper on the subject, viz., "On Very Rapid Electrical Oscillations" (Wied. *Ann.*, Vol. XXXI., page 421, 1887), he refers to a Paper by Colley, "On some New Methods for Observing Electrical Oscillations, with Applications" (*ibid.*, Vol. XXVI., page 432), who calls attention to the fact that Sir William Thomson in 1853 first showed the possibility of producing electrical oscillations by the discharge of a charged conductor, and gives references to all the investigations in the same direction which were known to him.

For the benefit of readers who may wish to pursue the subject further the list is reproduced below:—

Sir W. Thomson, "Mathematical and Physical Papers," Vol. I., page 540.

Feddersen, Poggendorff's *Annalen*, Vol. CIII., page 69, 1858; Vol. CVIII., page 497, 1859; Vol. CXII., page 452, 1861; Vol. CXIII., page 437, 1861; Vol. CXV., page 336, 1862; Vol. CXVI., page 132, 1862.

Kirchhoff, "Gesammelte Abhandlungen," page 168, containing remarks on, and corrections of some of Feddersen's results.

von Helmholtz, "Gesammelte Abhandlungen," Vol. I., page 531.

von Oettingen, Poggendorff's *Annalen*, Vol. CXV., page 115, 1862; and Jubelband, page 269, 1874.

Bernstein, Poggendorff's *Annalen*, Vol. XIII., page 142, 1828.

Schiller, Poggendorff's *Annalen*, Vol. CLII., page 535, 1872.

L. Lorenz, Wiedemann's *Annalen*, Vol. VII., page 161, 1879.

Mouton, Thèse, Paris, 1876. *Journal des Physique*, Vol. VI., pages 5 and 46, 1876.

Kolacek, Beiblatter zu Wiedemann's *Annalen*, Vol. VII., p. 541, 1883 (Abstract of a Paper published in the reports of the Bohemian Scientific Society in 1882).

Olearsky, Verhandlungen der Academie von Krakau, Vol. VII., p. 141, 1882.

Oberbeck, Wiedemann's *Annalen*, Vol. XVII., pp. 816 and 1,040, 1882; Vol. XIX., pp. 213 and 265, 1883.

Bichat et Blondlot, *Comptes Rendus*, Vol. XCIV., p. 1,590, 1882.

According to these investigations, the electrical oscillations produced in an open circuit by means of an induction coil are measured by ten thousandths of a second, while in the case of the oscillatory discharge of a Leyden jar they are about a hundred times as rapid, as was shown by Feddersen.

According to theory, still more rapid oscillations should be possible in an open circuit of wire of good conducting material, provided its ends are not connected with conductors of any considerable capacity; but it is not possible to determine from theory whether measurable oscillations are actually produced. Some observations of Hertz's led him to believe that under certain circumstances oscillations of this kind were produced, and his researches show that this is so, and that the oscillations are about a hundred times as rapid as those observed by Feddersen; so that their periods are measured by hundred millionths of a second, and, therefore, they occupy a position intermediate between acoustic and luminous vibrations.

Preliminary Experiments.—It is known that if in the secondary circuit of an induction coil there be inserted, in addition to the ordinary air space, across which sparks pass, a Riess spark micrometer, with its poles joined by a long wire,

the discharge will pass across the air space of the micrometer in preference to following the path of least resistance through the wire, provided this air space does not exceed a certain limit, and it is upon this principle that lightning protectors for telegraph lines are constructed. It might be expected that the sparks could be made to disappear by diminishing the length and resistance of the connecting wire; but Hertz finds that though the length of the sparks can be diminished in this way, it is almost impossible to get rid of them entirely, and they can still be observed when the balls of the micrometer are connected by a thick copper wire only a few centimetres in length.

This shows that there must be variations in the potential measureable in hundredths of a volt in a portion of the circuit only a few centimetres in length, and it also gives an indirect proof of the enormous rapidity of the discharge, for the difference of potential between the micrometer knobs can only be due to self-induction in the connecting wire. Now the time occupied by variations in the potential of one of the knobs must be of the same order as that in which these variations can be transmitted through a short length of a good conductor to the second knob. The resistance of the wire connecting the knobs is found to be without sensible effect on the results.

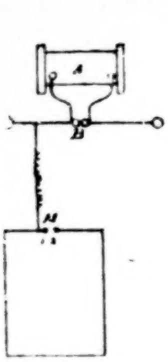


Fig. 1.

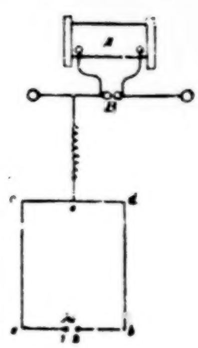


Fig. 2.

In Fig. 1, A is an induction coil and B a discharger. The wire connecting the knobs 1 and 2 of the spark micrometer M, consists of a rectangle, half a metre in length, of copper wire 2 millimetres in diameter. This rectangle is connected with the secondary circuit of the coil in the manner shown in the diagram, and when the coil is in action sparks, sometimes several millimetres in length, are seen to pass between the knobs 1 and 2, showing that there are violent electrical oscillations, not only in the secondary circuit itself, but in any conductor in contact with it. This experiment shows even more clearly than the previous one that the rapidity of the oscillations is comparable with the velocity of transmission of electrical disturbances through the copper wire, which according to all the evidence at our disposal is nearly equal to the velocity of light.

In order to obtain micrometer sparks some millimetres in length, a powerful induction coil is required, and the one used by Hertz was 52 centimetres in length and 20 centimetres in diameter, provided with a mercury contact breaker, and excited by six large Bunsen cells. The discharger terminals consisted of brass knobs 3 centimetres in diameter. The experiments showed that the phenomenon depends to a very great extent on the nature of the sparks at the discharger, the micrometer sparks being found to be much weaker when the discharge in the secondary circuit took place between two points, or between a point and a plate, than when knobs were used. The micrometer sparks were also found to be greatly enfeebled when the secondary discharge took place in a rarefied gas, and also when the sparks in the secondary were less than half a centimetre in length, while, on the other hand, if they exceeded 1½ centimetres the sparks could no longer be observed between the micrometer knobs. The length of secondary spark which was found to give the best results, and which was, therefore, employed in the further observations, was about three quarters of a centimetre.

Very slight differences in the nature of the secondary sparks were found to have great effect on those at the micrometer, and Hertz states that after some practice he was able to determine at once from the sound and appearance of the secondary spark whether it was of a kind to give the most powerful effects at the micrometer. The sparks which gave the best results were of a brilliant white colour, only slightly jagged, and accompanied by a sharp crack.

The influence of the spark is readily shown by increasing the distance between the discharger knobs beyond the striking distance, when the micrometer sparks disappear entirely, although the variations of potential are now greater than before. The length of the micrometer circuit has naturally an important influence on the length of the spark, as the greater its length the greater will be the retardation of the electrical wave in its passage through it from one knob of the micrometer to the other.

The material, the resistance, and the diameter of the wire of which the micrometer circuit is formed have very little influence on the spark. The potential variations cannot, therefore, be due to the resistance, and this was to be expected, for the rate of propagation of an electrical disturbance along a conductor depends mainly on its capacity and coefficient of self-induction, and only to a very small extent on its resistance. The length of the wire connecting the micrometer circuit with the secondary circuit of the coil is also found to have very little influence, provided it does not exceed a few metres in length. The electrical disturbances must therefore traverse it without undergoing any appreciable change. The position of the point of the micrometer circuit which is joined to the secondary circuit is, on the other hand, of the greatest importance, as would be expected, for if the point is placed symmetrically with respect to the two micrometer knobs the variations of potential will reach the latter in the same phase, and there will be no effect, as is verified by observation. If the two branches of the micrometer circuit on each side of the point of contact of the connection with the secondary are not symmetrical, the spark cannot be made to disappear entirely; but a minimum effect is obtained when the point of contact is about half-way between the micrometer knobs. This point may be called the null point.

Fig. 2 shows the arrangement employed, *e* being the null point of the rectangular circuit, which is 125 centimetres long by 80 centimetres broad. When the point of contact is at *c* or *b*, sparks of from 3 to 4 milimetres in length are observed; when it is at *e* no sparks are seen; but they can be made to reappear by shifting the point of contact a few centimetres to the right or left of the null point. It should be noted that sparks only a few hundredths of a milimetre in length can be observed. If when the point of contact is at *e* another conductor is placed in contact with one of the micrometer knobs the sparks reappear.

Now, the addition of this conductor cannot produce any alteration in the time taken by the disturbances proceeding from *e* to reach the knobs, and, therefore, the phenomenon cannot be due simply to single waves in the directions *ca* and *db* respectively, but must be due to repeated reflection of the waves until a condition of stationary vibration is attained, and the addition of the conductor to one of the knobs must diminish or prevent the reflection of the waves from that terminal. It must be assumed, then, that definite oscillations are set up in the micrometer circuit just as an elastic bar is thrown into definite vibrations by blows from a hammer. If this assumption is correct, the condition for the disappearance of the sparks at M will be that the vibration periods of the two branches *e*1 and *e*2 shall be equal. These periods are determined by the products of the coefficients of self induction of these conductors into the capacities of their terminals, and are practically independent of their resistances.

In confirmation of this, it is found that if when the point of contact is at *e* and the sparks have been made to reappear by connecting a conductor with one of the knobs, this conductor is replaced by one of greater capacity, the sparking is greatly increased. If a conductor of equal capacity, is connected with

other micrometer knob the sparks disappear again; the effect of the first conductor can also be counteracted by shifting the point of contact towards it, thereby diminishing the self-induction in that branch. The conclusions were further confirmed by the results obtained when coils of copper wire were inserted into one or other, and then into both of the branches of the micrometer circuit.

He supposed that as the self induction of iron wires is, for slow alternations, from eight to ten times that of copper wires, therefore a short iron wire would balance a long copper one; but this was not found to be the case, and he concludes that, owing to the great rapidity of the alternations, the magnetism of the iron is unable to follow them, and therefore has no effect on the self induction.

(To be continued.)

MANUFACTURE OF LIGHT.*

BY DR. OLIVER LODGE, F.R.S.

The conclusions at which we have arrived, that light is an electrical disturbance, and that light waves are excited by electric oscillations, must ultimately, and very shortly, have a practical import.

Our present systems of making light artificially are wasteful and ineffective. We want a certain range of oscillation, between 7,000 and 4,000 billion vibrations per second; no other is useful to us, because no other has any effect on our retina; but we do not know how to produce vibrations of this rate. We can produce a definite vibration of one or two hundred or thousand per second; in other words, we can excite a pure tone of definite pitch, and we can command any desired range of such tones continuously by means of bellows and a keyboard. We can also (though the fact is less well known) excite momentarily definite ethereal vibrations of some millions per second, as I have at length explained; but we do not at present seem to know how to maintain this rate quite continuously. To get much faster rates of vibration than this we have to fall back upon atoms. We know how to make atoms vibrate; it is done by what we call "heating" the substance, and if we could deal with individual atoms unhampered by others, it is possible that we might get a pure and simple mode of vibration from them. It is possible, but unlikely; for atoms, even when isolated, have a multitude of modes of vibration special to themselves, of which only a few are of practical use to us, and we do not know how to excite some without also the others. However, we do not at present even deal with individual atoms; we treat them crowded together in a compact mass, so that their modes of vibration are really infinite.

We take a lump of matter, say a carbon filament or a piece of lime, and by raising its temperature we impress upon it higher and higher modes of vibration, not transmuting the lower into the higher, but superposing the higher upon the lower, until at length we get such rates of vibration as our retina is constructed for, and we are satisfied. But how wasteful and indirect and empirical is the process. We want a small range of rapid vibrations, and we know no better than to make the whole series leading up to them. It is as though, in order to sound some little shrill octave of pipes in an organ, we were obliged to depress every key and every pedal, and to blow a young hurricane.

I have purposely selected as examples the more perfect methods of obtaining artificial light, wherein the waste radiation is only useless, and not noxious. But the old fashioned plan was cruder even than this; it consisted simply in setting something burning, whereby not only the fuel but the air was consumed, whereby also a most powerful radiation was produced in the waste waves of which we were content to sit stewing, for the sake of the minute, almost infinitesimal, fraction of it which enabled us to see.

Everyone knows now, however, that combustion is not a pleasant or healthy mode of obtaining light; but everybody does not realise that neither is incandescence a satisfactory and unwasteful method which is likely to be practised for more than a few decades, or perhaps a century.

Look at the furnaces and boilers of a great steam engine driving a group of dynamos, and estimate the energy expended; and then look at the incandescent filaments of the lamps excited by them, and estimate how much of their radiated energy is of real service to the eye. It will be as the energy of a pitch pipe to an entire orchestra.

It is not too much to say that a boy turning a handle could, if his energy were properly directed, produce quite as much real light as is produced by all this mass of mechanism and consumption of material.

There might, perhaps, be something contrary to the laws of Nature in thus hoping to get and utilise some specific kind of radiation without the rest; but Lord Rayleigh has shown in a short communication to the British Association at York* that it is not so, and that therefore we have a right to try to do it.

We do not yet know how it is true, but it is one of the things we have got to learn.

Anyone looking at a common glow worm must be struck with the fact that not by ordinary combustion, nor yet on the steam engine and dynamo principle, is that easy light produced. Very little waste radiation is there from phosphorescent things in general. Light of the kind able to affect the retina is directly emitted, and for this, for even a large supply of this, a modicum of energy suffices.

Solar radiation consists of waves of all sizes, it is true; but then solar radiation has innumerable things to do besides making things visible. The whole of its energy is useful. In artificial lighting nothing but light is desired; when heat is wanted it is best obtained separately, by combustion. And so soon as we clearly recognise that light is an electrical vibration, so soon shall we begin to beat about for some mode of exciting and maintaining an electrical vibration of any required degree of rapidity. When this has been accomplished, the problem of artificial lighting will have been solved.

ON RECENT DEVELOPMENTS OF THE COWLES' ALUMINIUM PROCESS.†

BY R. E. CROMPTON.

It is unnecessary to again describe the earlier stages of the Brothers Cowles invention of the electric furnace. I confine myself to a description of such parts of the new plant which has been recently put down at Milton, near Stoke upon Trent, that I think will be of general scientific interest.

The experience in America at the works at Lockport, Ohio, showed conclusively that great economies were to be expected from increasing the size of the furnaces and the strength of the electric currents employed to work them; but no current larger than 3,000 amperes had been used up to the time that the Milton Works were planned.

Mr. Eugene Cowles came over to England to ascertain whether English makers of dynamo machines were prepared to supply one 60 per cent. larger than Mr. Brush's "Colossus," which had been made specially for them in America, and which was then the largest direct current machine in the world. He prepared his specification for a dynamo to give a current of 5,000 amperes at 60 volts, and eventually Messrs. Crompton's designs and tender were accepted.

The works were built near the Milton Station on the North Staffordshire Railway; the boilers for generating the steam required are of the Babcock-Wilcox type, and are provided with mechanical stokers; the steam engine is of 600 horse-power, and is a compound condensing horizontal tandem, made by Messrs. Pollit and Wigzel, of Sowerby Bridge; it is furnished with an exceedingly perfect centrifugal governor, which maintains the speed accurately at seventy six revolutions in spite of very great fluctuations in the load. The electrical

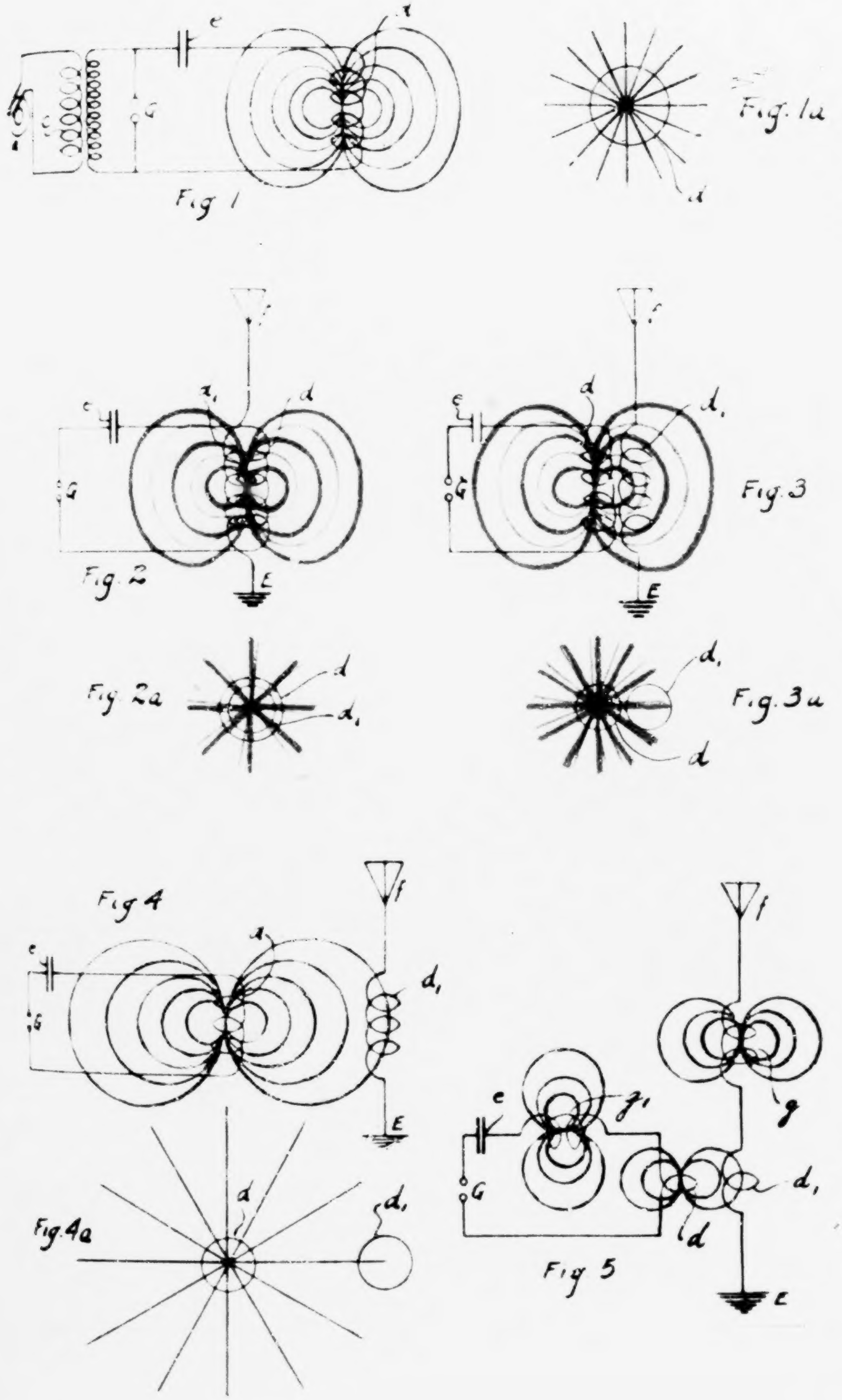
* Extract from "Modern Views of Electricity," *Nature*, August 30, by kind permission of the author.

* B. A. Report, 1881, p. 526.

† Paper read before the British Association meeting (Section G), at Bath, September, 1888.

DEFENDANT'S EXHIBIT M-2

Loftin Sketch F



Loftin Sketch G DEFENDANT'S EXHIBIT Q-2

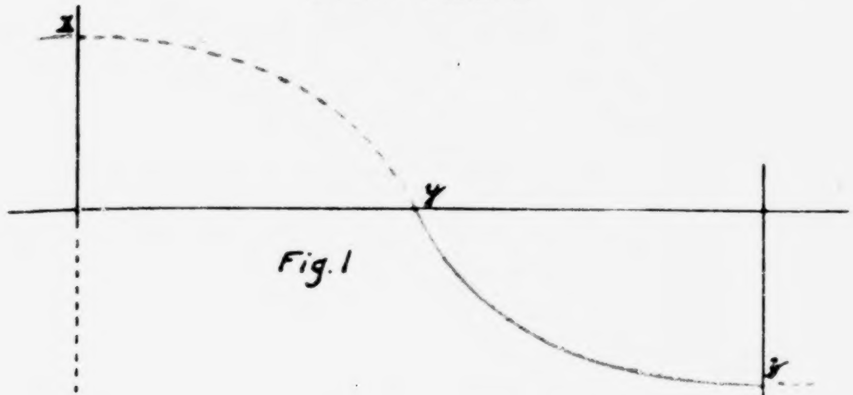


Fig. 1

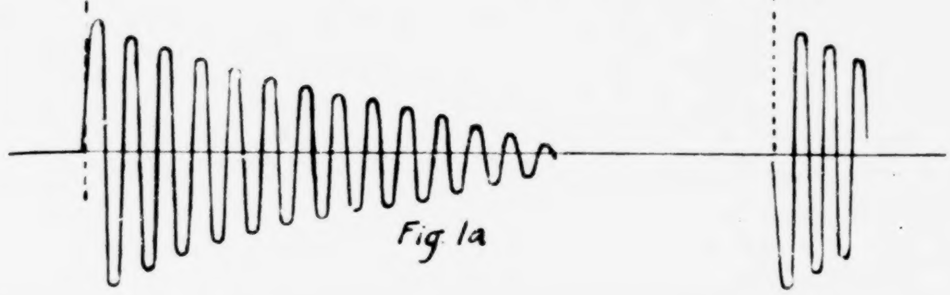


Fig. 1a

Tight Coupling
Plain gap
LC = LC

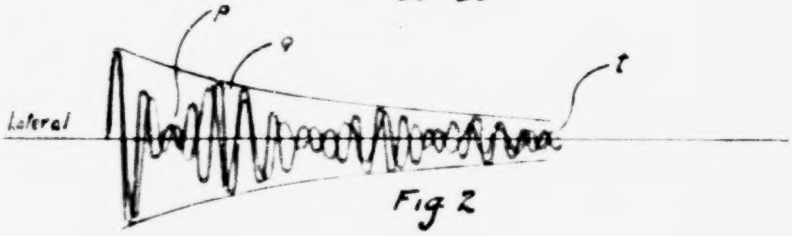


Fig. 2

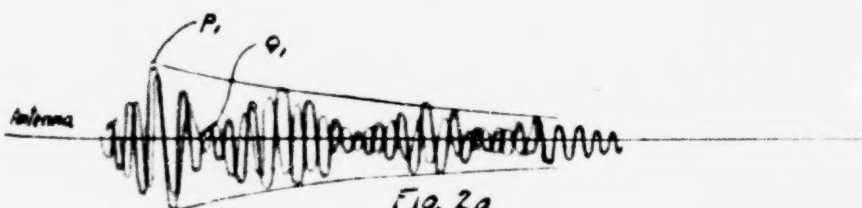


Fig. 2a

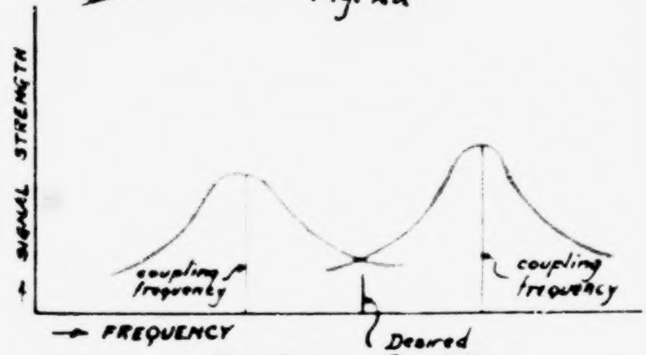


Fig. 2b

Loftin Sketch H

DEFENDANT'S EXHIBIT P-2

Loose Coupling Plain gap.

Antennae LC less than lateral LC

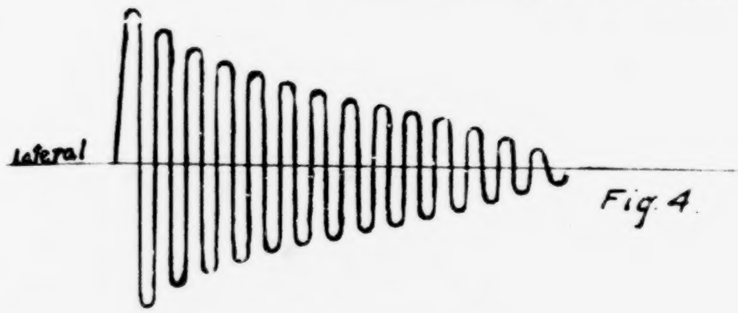


Fig. 4

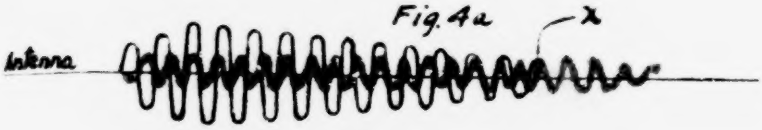


Fig. 4a

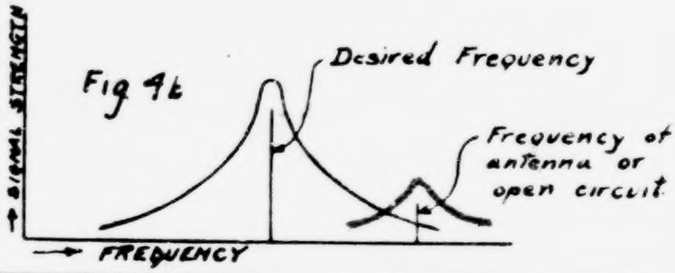


Fig 4b

Loose coupling Plain gap

LC = LC

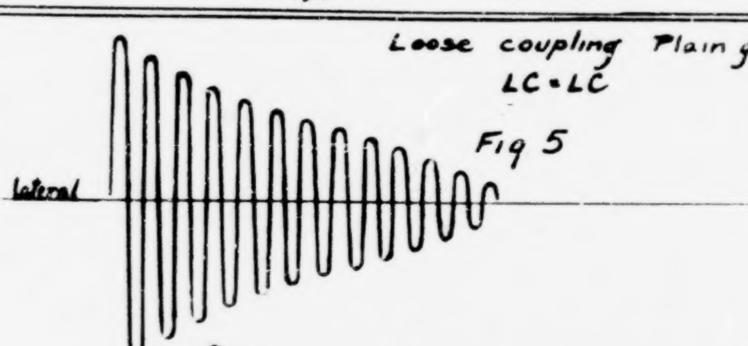


Fig 5

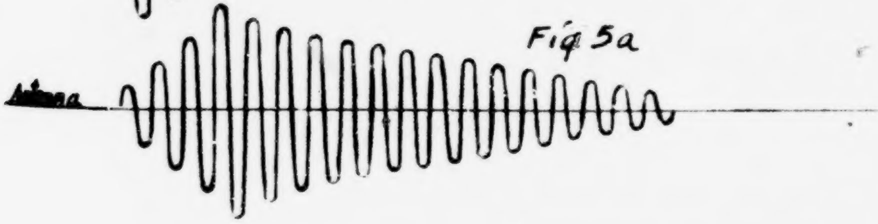


Fig 5a

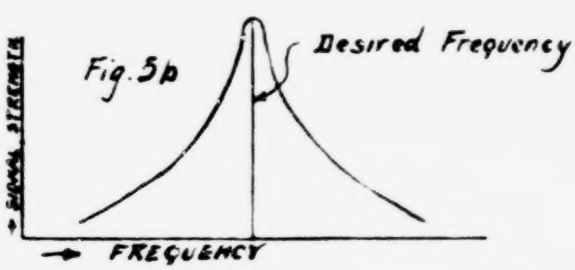
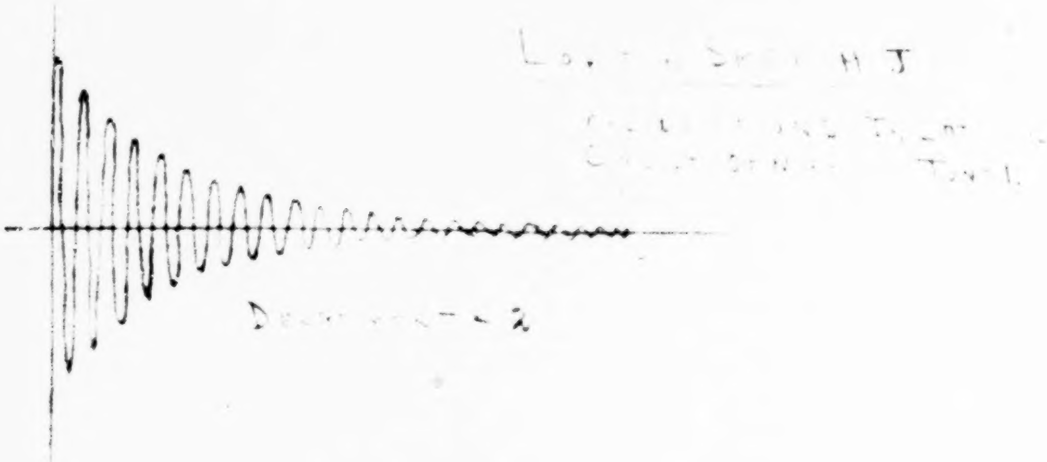


Fig. 5b

DEFENDANT'S EXHIBIT Q-2



No. 640,516. Patented Jan. 2, 1900.

M. I. PUPIN.

ELECTRICAL TRANSMISSION BY RESONANCE CIRCUITS.

(Application filed May 28, 1895. Renewed Oct. 14, 1899.)

(No Model.)

Fig. 1.

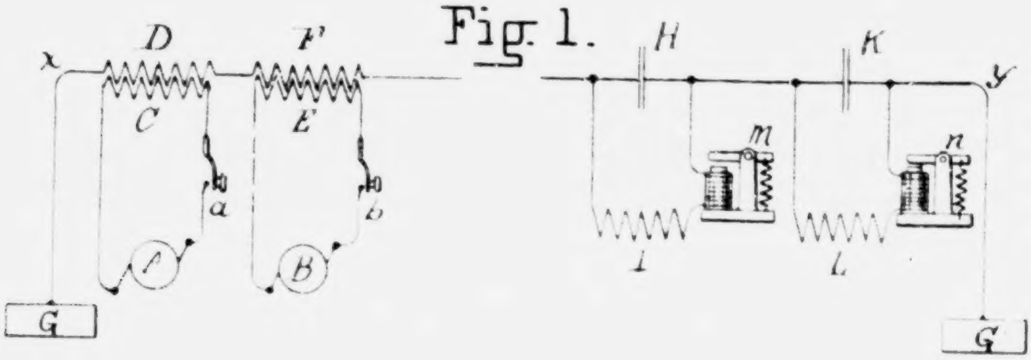


Fig. 2.

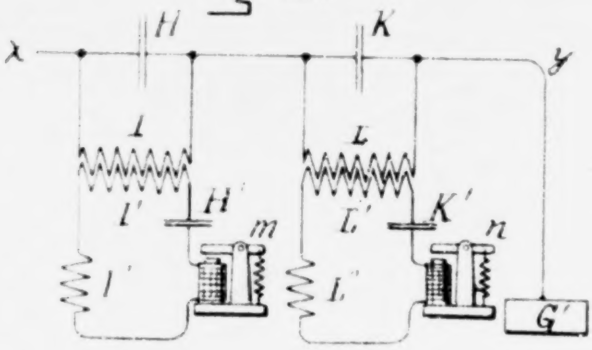
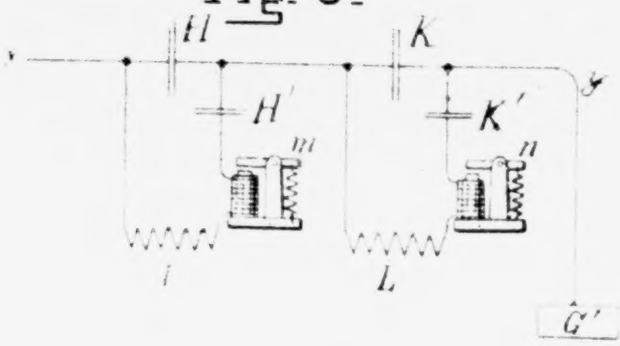


Fig. 3.



Witnesses:

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Amos Bilsarie

Inventor,

Michael I. Pupin,

by Thomas Ewing Jr

Attorney.

UNITED STATES PATENT OFFICE.

MICHAEL I. PUPIN, OF NEW YORK, N. Y.

ELECTRICAL TRANSMISSION BY RESONANCE-CIRCUITS.

SPECIFICATION forming part of Letters Patent No. 640,516, dated January 2, 1900.

Application filed May 28, 1895. Renewed October 14, 1896. Serial No. 608,890. (No model.)

To all whom it may concern:

Be it known that I, MICHAEL I. PUPIN, a citizen of the United States of America, residing in the city, county, and State of New York, have invented certain new and useful Improvements in Electrical Transmission by Resonance-Circuits, of which the following is a specification.

If a condenser be inserted in a line and a self-induction coil be connected in shunt with this condenser, then an alternating current impressed upon the line will under certain conditions be greater in the shunt-circuit than in the line itself. The shunt-circuit in this case may be considered as a step-up transformer of the line-current. This subject has been discussed at considerable length in Vol. I of Fleming's treatise on the alternate-current transformer and also in Blakesley's book on alternating currents. There have been, however, no experimental data to guide one in determining the exact limitations within which the results of pure theory are applicable. Such limitations exist, and unless they are clearly understood this method of step-up transformation indicated by the theory fails completely. I have studied experimentally this method of step-up current transformation and have discovered the necessary and sufficient conditions under which such a shunt-circuit is resonant. These conditions may be stated briefly, as follows:

First. The capacity of the condenser and the self-induction of the shunt-coil must be so related as to bring the shunt-circuit in resonance with the line-current.

Second. The shunt-coil should either contain no iron at all, or if it contains iron the quantity of it should be very small, and it should be well laminated and should not form a closed magnetic circuit. This is true of resonance-circuits of every form, it being a general principle and not one limited to shunt-circuits that the use of iron should be avoided in such circuits.

Third. The ohmic resistance of the shunt-circuit should be as small as possible and certainly smaller than the resistance of the line.

By employing a well-constructed condenser and a low-resistance self-induction coil without iron I have succeeded in obtaining from a given line-current a resonant current that is twenty times as large as the line-current. I believe that I am the first to investigate experimentally the behavior of such resonant shunt-circuits and to discover the conditions under which they will operate in a manner indicated by the theory. At any rate I consider myself to be the first to apply such circuits to the solution of the practical problem solved by the following invention.

In multiple telegraphy by resonance-circuit it is necessary to employ selective circuits at the receiving end of the line. The employment of resonance shunt-circuits for selective receiving circuits offers many important advantages.

By a "resonance-circuit" is meant one which has self-induction and capacity and therefore a natural period. When the self-induction and capacity are properly adjusted so as to give it the period of the impressed electromotive force, the resonance-circuit becomes resonant to this electromotive force.

The arrangement of resonance shunt-circuits herein shown gives less self-induction at the receiving end of the line than any other form of resonance-circuit. They are also under all circumstances step-up transformers of the line-current and are less apt when rendered resonant to interfere with each other than resonance-circuits of any other form.

In the accompanying drawings, which form a part of this specification, Figure 1 is a diagrammatic view of the transmitter and receiver stations, the line-wire being broken away. Fig. 2 is a diagrammatic view of the receiver-station in a somewhat-modified system. Fig. 3 is another diagrammatic view of the receiver-station in another modified system.

Referring now more particularly to Fig. 1, $x\ y$ is a telegraph-line grounded at its ends G and G'. At the sending end of the line two alternators A and B impress on the line $x\ y$ by means of the coils C D and E F two electromotive forces of different frequencies, say of one hundred and fifty and two hundred and fifty vibrations per second, respectively. The keys a and b serve to open and close the inducing alternator-circuits, and thus impart to the line alternating-current waves.

With a long line, such as is usually employed in telegraph systems of the general

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type here described, the two circuits A a C and B b E are practically independent of each other. They may be varied in arrangement and still retain essential independence. Two circuits forming parts of a system of electric conductors are independent of each other when the energy generated in one by the action of an electromotive force acting in the other is small in comparison with the energy generated in the whole system by the action of this same electromotive force. In order to secure this mutual independence in the transmitter-circuits, it is important that they should act upon the main line through elements which, like the coils D and F, are connected in the main line in series. In practice it is found advantageous to throw the currents onto the line at the transmitting end through transformers. And in case of lines that are short in comparison with the wave length of the current transmitted the selectivity of the receiving resonance-circuits is more pronounced and independent of what is going on at the transmitting end of the line when the secondary coils of the transformers at the transmitting end are all placed in series in the line than when they are placed in multiple. At the receiving end it is important to have condensers with shunts around them containing self-induction coils forming parts of the main line. It is obvious that the coils I and L are just as much in series in the main line as are the condensers H and K.

By the term "transmitter-circuits" I do not mean to designate transmitter branches connected to a line-wire in multiple with each other. Such branches, of course, cannot be independent of each other, since changes in the resistance and self-induction of one will appreciably affect the others.

At the receiving end condensers H and K, of adjustable capacity, are inserted in the line in series, and each condenser is shunted by a coil of adjustable self-induction containing no iron. These coils are indicated in Fig. 1 by the letters I and L. The capacity of the condenser H and the self-induction of the coil I being such that the natural period or frequency of the shunt or resonance circuit H I is the same as the period of one of the electromotive forces which produce the current coming over the line—say that having a periodicity of one hundred and fifty per second—this circuit H I will be in resonance with the current and therefore will act selectively with respect to it. In the same manner by adjusting the electromagnetic constants of the resonant shunt circuit, which contains coil L, this resonance circuit is made to act selectively with respect to the other current on the line. These resonance receiving-circuits are, like the transmitting-circuits, mutually independent, a current flowing in one generating no appreciable current in another. If, therefore, the periodicity of the electromotive force impressed by circuit A C a be one hundred and fifty and that of B E b be two hundred and fifty, we shall have, whenever the key a closes the circuit A C a, a resonant current of one hundred and fifty periods in the resonant shunt-circuit H I. Similarly when the key b closes the circuit B E b there will be a resonant current of two hundred and fifty periods in the local circuit K L. If both keys are closed simultaneously and therefore both alternators are acting simultaneously upon the line, there will be a resonant current with the frequency of one hundred and fifty in the circuit H I and there will be a resonant current with a frequency of two hundred and fifty in the circuit K L.

It is evident that theoretically any number of resonance shunt circuits may be employed at the receiving end of the line, each made resonant (by a proper adjustment of its electromagnetic constants) to one of the periodic currents impressed on the line at the transmitting end.

Referring now more particularly to Fig. 2, which represents the receiving end of the line and can be hitched onto the transmitting end shown in Fig. 1 instead of the receiving end shown in that figure, I show a resonance-circuit H I and K L. The condensers H and K, as in Fig. 1, are in series in the line; but I control the frequency of H I by means of a circuit H' I I', which contains the secondary coil of the induction-coil I I and the supplemental condenser H' and a self-induction coil I'. This system is in its practical operation the same as that of Fig. 1. In each the supplemental condenser H' and K' and the self-induction coil affect the constants of the resonant shunt circuits, and by adjusting one or both the natural periods of the resonant shunt circuits H I and K L can be adjusted until they equal the desired frequencies; but instead of indirectly affecting the constants of the resonant shunt circuits by means of the supplemental condenser and induction coils, as in Fig. 2, I can put the supplemental condensers directly in the resonant shunt circuits. This is shown in Fig. 3, which, like Fig. 2, represents a modification of the receiving end shown in Fig. 1. The periodicities or frequencies of the induction-circuits H H' I and K K' L can be adjusted by adjusting the capacity of the supplemental condensers H' and K' and the self-induction coils I and L. The forms shown in Figs. 2 and 3 are preferable to the form shown in Fig. 1.

Each resonant shunt circuit contains an electromagnet m or n, which may be taken as representing generically a translation device operated by the energy of the current which traverses the resonant shunt circuit. It may be operated by this current either directly or indirectly. It is shown in Fig. 1 as operated directly, since the translating device is included directly in the resonant shunt circuit.

The disposition of the coils and condensers as shown in Figs. 2 and 3 does not differ in principle from that shown in Fig. 1, yet it

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should be noted here that my experience shows these dispositions to be more effective under certain conditions than that of Fig. 1. The dispositions give the resonant shunt-circuits a greater selectivity, and therefore I find these preferable in cases where a large number of resonant receiving-circuits are to be employed whose periods are near each other.

I do not claim in this application the method of distributing the electrical energy of periodic currents, which consists in throwing a number of such currents of different frequencies upon a single line and conveying the several energies of these currents each selectively to a separate electrical translating device; nor do I claim herein a system of distribution of electrical energy comprising a main line, means for impressing multiperiodic electromotive forces thereon, branch lines connected with the main line each having its self-induction and capacity so related as to be permeable to alternating currents of a given frequency, and an electrical receiving device in each branch line; nor do I broadly claim any method of or apparatus for distributing electromotive forces of different frequencies, each selectively, to a separate electrical translating device by the proper proportioning of the electromagnetic constants of the parts of the electrical system to be made selective and by which the translating devices are controlled either with or without any method of or arrangement of apparatus for developing upon a main line the electromotive forces of different desired frequencies independently of each other and simultaneously or otherwise, because these broad inventions are claimed substantially in my other application, Serial No. 501,092, filed February 23, 1894, for multiple telegraphy and which application is now involved in interference; nor do I broadly claim the combination, in an electric circuit, of means for imposing upon said circuit one or more electromotive forces of previously-selected periodicities, one or more circuits in inductive relation to said first-named circuit, and means for tuning the said inductively-related circuit or circuits each in resonance with one of said periodic electromotive forces and independently of the rest of the system, with or without additional means for also tuning separate branches connected to the first-named circuit, with which branches the other circuits named are inductively related, these being claimed in my other application for improvements in telegraphy, filed January 28, 1895, Serial No. 536,488, and at the transmitting-stations I prefer to use the arrangement shown and claimed in my other application for improvements in distributing electrical energy, filed May 21, 1895, Serial No. 550,058, renewed December 4, 1899, as Serial No. 739,207.

Where in the claims I specify the combination of a line-wire or a line with one or more resonant circuits without indicating that there are both receiving and transmitting circuits connected by a line-wire, I wish it to be distinctly understood that I do not limit myself to any specific means or method of transmitting from one station to another nor to any specific connection between the transmitting and receiving stations; nor do I intend, except where it is specified in the claims, to indicate definitely the arrangement which should be employed at the transmitting-station or to limit the claims with respect thereto.

It is obvious that many modifications may be made in my arrangement without departing from the spirit of my invention.

Having now fully described my invention, what I claim, and desire to secure by Letters Patent of the United States, is—

1. In an electric system the combination of a main line, mutually-independent exciting-circuits, which act upon the main line through elements placed therein in series, independent means for impressing an electromotive force of desired frequency upon the main line at each exciting-circuit, mutually-independent receiving-circuits, means for tuning each receiving-circuit to resonance with one of the impressed electromotive forces, and translating devices operated by the currents in the receiving-circuits, substantially as described.

2. In an electric system the combination of a main line, mutually-independent exciting-circuits which act upon the main line through elements placed therein in series, independent means for impressing an electromotive force of desired frequency upon the main line at each exciting-circuit, mutually-independent receiving-circuits which are acted upon from the main line through elements connected therein in series, means for tuning each receiving-circuit to resonance with one of the impressed electromotive forces, and translating devices operated by the currents in the receiving-circuits, substantially as described.

3. In an electric system the combination of a main line, mutually-independent exciting-circuits which act upon the main line through transformers the secondary coils of which are placed in the main line in series, independent means for impressing an electromotive force of desired frequency upon the main line at each exciting-circuit, condensers in series in the main line, a shunt around each condenser containing a self-induction coil, thus forming mutually-independent receiving-circuits, means for tuning each receiving-circuit to one of the impressed electromotive forces, and translating devices operated by the currents in the receiving-circuits, substantially as described.

4. In an electrical system, the combination of a line-wire, a condenser therein, a shunt around the condenser containing a self-induction coil without an iron core thus forming a resonance circuit and means for adjusting the electromagnetic constants of the resonance-circuit so as to give it a desired periodicity, substantially as described.

5. In a multiplex signaling system the com-

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bination of line-wire, means for impressing thereon, independently of each other, electromotive forces of two or more distinct periodicities, two or more condensers in series in the line; a shunt around each condenser containing a self-induction coil, each condenser with its shunt-coil forming an independent resonance circuit, receiving instruments therein, and means for adjusting the electromagnetic constants of these resonance-circuits, so as to give to each such circuit a periodicity corresponding to one of the impressed electromotive forces, substantially as described.

6. In an electrical system, the combination of a line-wire, means for impressing thereon a current of a given frequency, a condenser in the line, a shunt around the condenser containing a self-induction coil without an iron core thus forming a resonance-circuit, and means for adjusting the electromagnetic constants of the resonance-circuit so as to give it a periodicity corresponding with the frequency of the current to be impressed upon the line, substantially as described.

7. In an electrical system, the combination of the line, means for impressing thereon a current produced by two or more electromotive forces of different frequencies which are independent of each other, two or more condensers in the line in series, a shunt around each condenser containing a self-induction coil, thus forming resonance-circuits, circuits in inductive relation thereto and containing condensers and self-induction coils supplemental to those of the resonance-circuits, receiving instruments, and means for adjusting the electromagnetic constants of these resonance-circuits so as to give each such circuit a periodicity corresponding to the frequency of one of the electromotive forces impressed upon the line, substantially as described.

8. In an electrical system, the combination of a line-wire, two or more condensers connected in series therein, a shunt around each condenser containing a self-induction coil, thus forming resonance circuits, receiving instruments therein, a supplemental condenser in each of the resonance-circuits, and means for adjusting the constants of each resonance-circuit, so as to give it a desired periodicity, substantially as described.

9. In an electrical system, the combination of a line-wire, means for impressing thereon a current produced by two or more electromotive forces of different desired frequencies, two or more condensers in the line in series, a shunt around each condenser containing a self-induction coil, thus forming resonance-circuits, means for adjusting the constants of each resonance-circuit so as to give each a periodicity corresponding to the frequency of one of the electromotive forces, and translating devices each operated by the energy of the current traversing one of the resonance-circuits, substantially as described.

10. A resonance-circuit in which the self-induction coil employed to give the circuit a definite periodicity contains no iron, substantially as described.

Signed in New York this 25th day of May, 1895.

MICHAEL I. PUPIN.

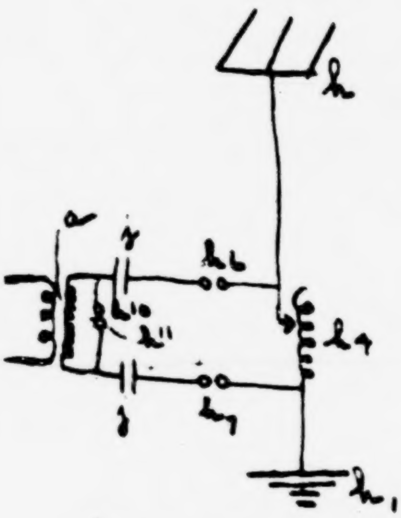
Witnesses:

S. KATHARINE PUPIN,

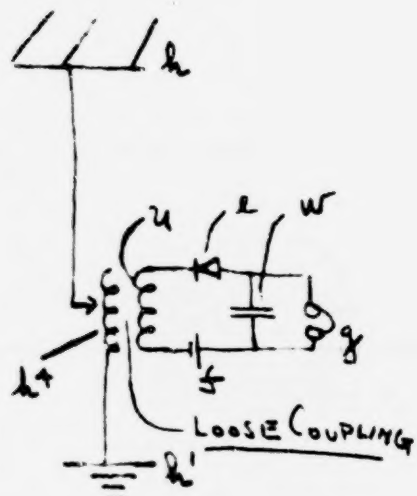
HY. H. WHITCOMB.

DEFENDANT'S EXHIBIT V-2

LOFTIN SKETCH L



LODGE TRANSMITTER
FIG 4 and DESCRIPTION

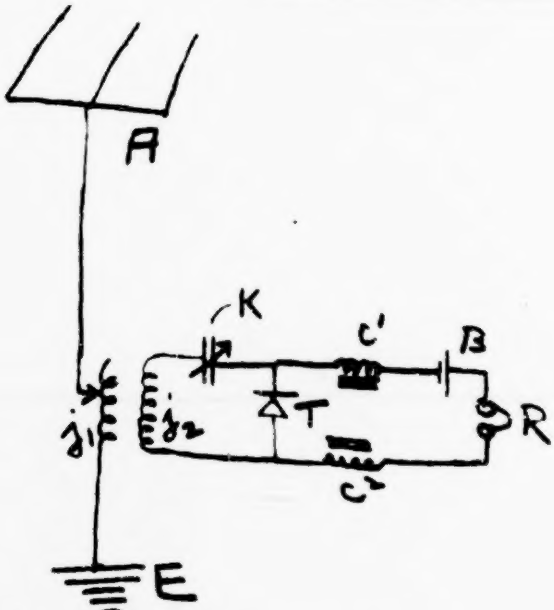


LODGE RECEIVER
FIG 13 and DESCRIPTION

LODGE PATENT 609,154
Aug 16, 1898

DEFENDANT'S EXHIBIT W-2

LOFTIN SKETCH M



MARCONI Receiver 1899
Patent 627,650 of June 27-1899
FIG I and DESCRIPTION

[signature]

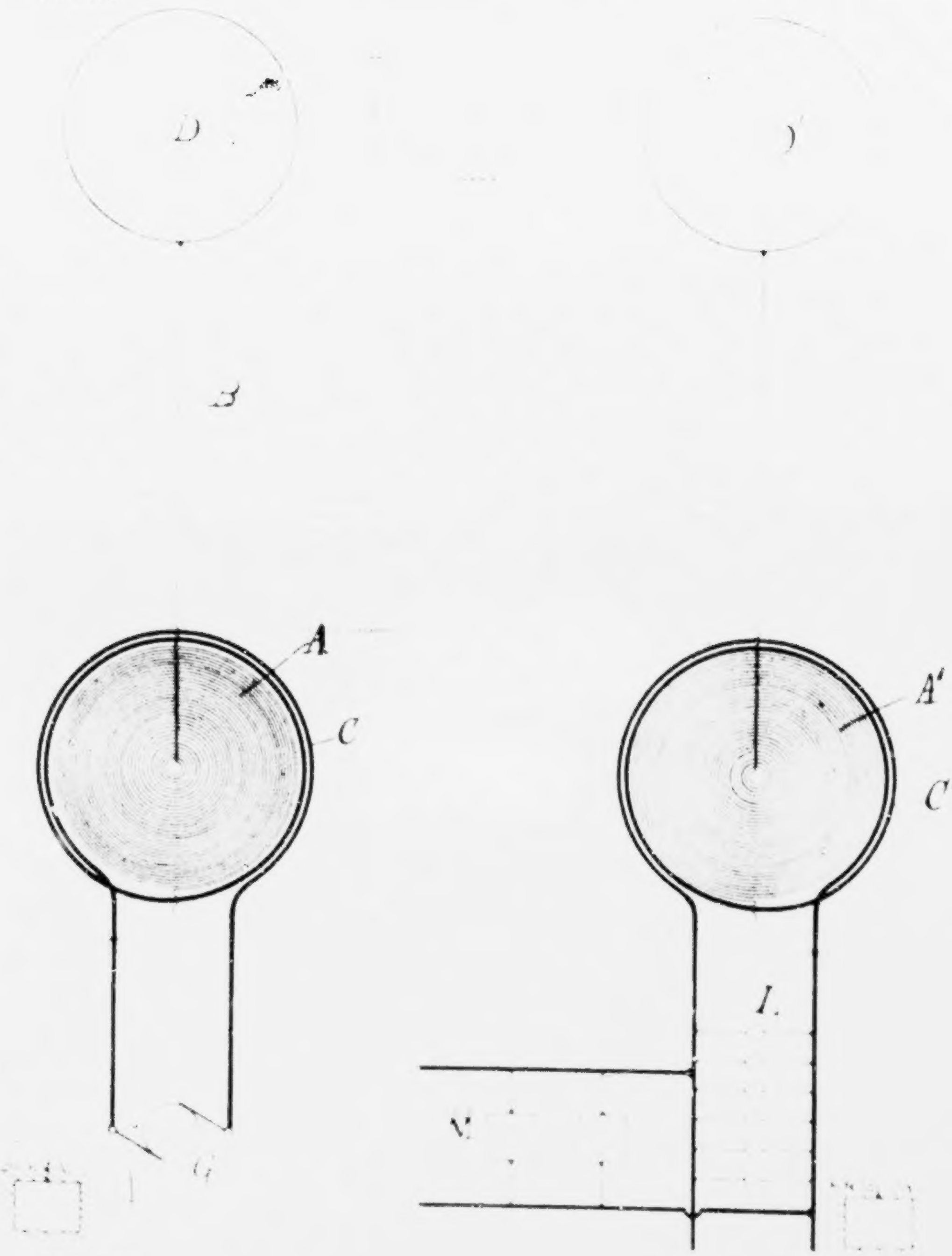
No. 645,576 Patented Mar. 20, 1900.

N. TESLA.

SYSTEM OF TRANSMISSION OF ELECTRICAL ENERGY.

Application filed Sept. 2, 1897.

No Model.



WITNESSES

Drury W. Cooper

INVENTOR

Nikola Tesla

BY

Kerr, Curtis & Page

ATTORNEYS.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

SYSTEM OF TRANSMISSION OF ELECTRICAL ENERGY.

SPECIFICATION forming part of Letters Patent No. 645,576, dated March 20, 1900.

Application filed September 2, 1897. Serial No. 650,343. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Systems of Transmission of Electrical Energy, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

It has been well known heretofore that by rarefying the air inclosed in a vessel its insulating properties are impaired to such an extent that it becomes what may be considered as a true conductor, although one of admittedly very high resistance. The practical information in this regard has been derived from observations necessarily limited in their scope by the character of the apparatus or means heretofore known and the quality of the electrical effects producible thereby. Thus it has been shown by William Crookes in his classical researches, which have so far served as the chief source of knowledge of this subject, that all gases behave as excellent insulators until rarefied to a point corresponding to a barometric pressure of about seventy-five millimeters, and even at this very low pressure the discharge of a high-tension induction coil passes through only a part of the attenuated gas in the form of a luminous thread or arc, a still further and considerable diminution of the pressure being required to render the entire mass of the gas inclosed in a vessel conducting. While this is true in every particular so long as electromotive or current impulses such as are obtainable with ordinary forms of apparatus are employed, I have found that neither the general behavior of the gases nor the known relations between electrical conductivity and barometric pressure are in conformity with these observations when impulses are used such as are producible by methods and apparatus devised by me and which have peculiar and hitherto unobserved properties and are of effective electromotive forces, measuring many hundred thousands or millions of volts. Through the continuous perfection of these methods and apparatus and the investigation of the actions of these current impulses I have been led to the discovery of certain highly-important and useful facts which have hitherto been unknown. Among these and bearing directly upon the subject of my present application are the following: First, that atmospheric or other gases, even under normal pressure, when they are known to behave as perfect insulators, are in a large measure deprived of their dielectric properties by being subjected to the influence of electromotive impulses of the character and magnitude I have referred to and assume conducting and other qualities which have been so far observed only in gases greatly attenuated or heated to a high temperature, and, second, that the conductivity imparted to the air or gases increases very rapidly both with the augmentation of the applied electrical pressure and with the degree of rarefaction, the law in this latter respect being, however, quite different from that heretofore established. In illustration of these facts a few observations, which I have made with apparatus devised for the purposes here contemplated, may be cited. For example, a conductor or terminal, to which impulses such as these here considered are supplied, but which is otherwise insulated in space and is remote from any conducting-bodies, is surrounded by a luminous flame-like brush or discharge often covering many hundreds or even as much as several thousands of square feet of surface, this striking phenomenon clearly attesting the high degree of conductivity which the atmosphere attains under the influence of the immence electrical stresses to which it is subjected. This influence is, however, not confined to that portion of the atmosphere which is discernible by the eye as luminous and which, as has been the case in some instances actually observed, may fill the space within a spherical or cylindrical envelop of a diameter of sixty feet or more, but reaches out to far remote regions, the insulating qualities of the air being, as I have ascertained, still sensibly impaired at a distance many hundred times that through which the luminous discharge projects from the terminal and in all probability much farther. The distance extends with the increase of the electromotive force of the impulses, with the diminution of the density of the atmosphere, with the elevation of the active terminal above the ground, and also, apparently, in a slight measure, with the degree of moisture contained in

the air. I have likewise observed that this region of decidedly noticeable influence continuously enlarges as time goes on, and the discharge is allowed to pass not unlike a conflagration which slowly spreads, this being possibly due to the gradual electrification or ionization of the air or to the formation of less insulating gaseous compounds. It is, furthermore, a fact that such discharges of extreme tensions, approximating those of lightning, manifest a marked tendency to pass upward away from the ground, which may be due to electrostatic repulsion, or possibly to slight heating and consequent rising of the electrified or ionized air. These latter observations make it appear probable that a discharge of this character allowed to escape into the atmosphere from a terminal maintained at a great height will gradually leak through and establish a good conducting path to more elevated and better conducting air strata, a process which possibly takes place in silent lightning discharges frequently witnessed on hot and sultry days. It will be apparent to what an extent the conductivity imparted to the air is enhanced by the increase of the electromotive force of the impulses when it is stated that in some instances the area covered by the flame discharge mentioned was enlarged more than sixfold by an augmentation of the electrical pressure, amounting scarcely to more than fifty per cent. As to the influence of rarefaction upon the electric conductivity imparted to the gases it is noteworthy that, whereas the atmospheric or other gases begin ordinarily to manifest this quality at something like seventy-five millimeters barometric pressure with the impulses of excessive electromotive force to which I have referred, the conductivity, as already pointed out, begins even at normal pressure and continuously increases with the degree of tenuity of the gas, so that at, say, one hundred and thirty millimeters pressure, when the gases are known to be still nearly perfect insulators for ordinary electromotive forces, they behave toward electromotive impulses of several millions of volts like excellent conductors, as though they were rarefied to a much higher degree. By the discovery of these facts and the perfection of means for producing in a safe, economical, and thoroughly practicable manner current impulses of the character described it becomes possible to transmit through easily accessible and only moderately rarefied strata of the atmosphere electrical energy not merely in insignificant quantities, such as are suitable for the operation of delicate instruments and like purposes, but also in quantities suitable for industrial uses on a large scale up to practically any amount and, according to all the experimental evidence I have obtained, to any terrestrial distance. To conduce to a better understanding of this method of transmission of energy and to distinguish it clearly, both in its theoretical aspect and in its practical bearing, from other known modes of transmission, it is useful to state that all previous efforts made by myself and others for transmitting electrical energy to a distance without the use of metallic conductors, chiefly with the object of actuating sensitive receivers, have been based, in so far as the atmosphere is concerned, upon those qualities which it possesses by virtue of its being an excellent insulator, and all these attempts would have been obviously recognized as ineffective if not entirely futile in the presence of a conducting atmosphere or medium. The utilization of any conducting properties of the air for purposes of transmission of energy has been hitherto out of the question in the absence of apparatus suitable for meeting the many and difficult requirements, although it has long been known or surmised that atmospheric strata at great altitudes—say fifteen or more miles above sea level—are, or should be, in a measure, conducting, but assuming even that the indispensable means should have been produced then still a difficulty, which in the present state of the mechanical arts must be considered as insuperable, would remain—namely, that of maintaining terminals at elevations of fifteen miles or more above the level of the sea. Through my discoveries before mentioned and the production of adequate means the necessity of maintaining terminals at such inaccessible altitudes is obviated and a practical method and system of transmission of energy through the natural media is afforded essentially different from all those available up to the present time and possessing, moreover, this important practical advantage, that whereas in all such methods or systems heretofore used or proposed but a minute fraction of the total energy expended by the generator or transmitter was recoverable in a distant receiving apparatus by my method and appliances it is possible to utilize by far the greater portion of the energy of the source and in any locality however remote from the same.

Expressed briefly, my present invention, based upon these discoveries, consists then in producing at one point an electrical pressure of such character and magnitude as to cause thereby a current to traverse elevated strata of the air between the point of generation and a distant point at which the energy is to be received and utilized.

In the accompanying drawing a general arrangement of apparatus is diagrammatically illustrated such as I contemplate employing in the carrying out of my invention on an industrial scale—as, for instance, for lighting distant cities or districts from places where cheap power is obtainable.

Referring to the drawing, A is a coil, generally of many turns and of a very large diameter, wound in spiral form either about a magnetic core or not, as may be found necessary. C is a second coil, formed of a conductor of much larger section and smaller

length, wound around and in proximity to the coil A. In the transmitting apparatus the coil A constitutes the high-tension secondary and the coil C the primary of much lower tension of a transformer. In the circuit of the primary C is included a suitable source of current G. One terminal of the secondary A is at the center of the spiral coil, and from this terminal the current is led by a conductor B to a terminal D, preferably of large surface, formed or maintained by such means as a balloon at an elevation suitable for the purposes of transmission, as before described. The other terminal of the secondary A is connected to earth and, if desired, also to the primary in order that the latter may be at substantially the same potential as the adjacent portions of the secondary, thus insuring safety. At the receiving-station a transformer of similar construction is employed, but in this case the coil A', of relatively-thin wire, constitutes the primary and the coil C', of thick wire or cable, the secondary of the transformer. In the circuit of the latter are included lamps L, motors M, or other devices for utilizing the current. The elevated terminal D' is connected with the center of the coil A', and the other terminal of said coil is connected to earth and preferably, also, to the coil C' for the reasons above stated.

It will be observed that in coils of the character described the potential gradually increases with the number of turns toward the center, and the difference of potential between the adjacent turns being comparatively small a very high potential, impracticable with ordinary coils, may be successfully obtained. It will be, furthermore, noted that no matter to what an extent the coils may be modified in design and construction, owing to their general arrangement and manner of connection, as illustrated, those portions of the wire or apparatus which are highly charged will be out of reach, while those parts of the same which are liable to be approached, touched, or handled will be at or nearly the same potential as the adjacent portions of the ground, this insuring, both in the transmitting and receiving apparatus and regardless of the magnitude of the electrical pressure used, perfect personal safety, which is best evidenced by the fact that although such extreme pressures of many millions of volts have been for a number of years continuously experimented with no injury has been sustained neither by myself or any of my assistants.

The length of the thin-wire coil in each transformer should be approximately one-quarter of the wave length of the electric disturbance in the circuit, this estimate being based on the velocity of propagation of the disturbance through the coil itself and the circuit with which it is designed to be used. By way of illustration if the rate at which the current traverses the circuit, including the coil, be one hundred and eighty-five thousand miles per second then a frequency of nine hundred and twenty-five per second would maintain nine hundred and twenty-five stationary waves in a circuit one hundred and eighty-five thousand miles long and each wave would be two hundred miles in length. For such a low frequency, to which I shall resort only when it is indispensable to operate motors of the ordinary kind under the conditions above assumed, I would use a secondary of fifty miles in length. By such an adjustment or proportioning of the length of wire in the secondary coil or coils the points of highest potential are made to coincide with the elevated terminals D D', and it should be understood that whatever length be given to the wires this condition should be complied with in order to attain the best results.

As the main requirement in carrying out my invention is to produce currents of an excessively-high potential, this object will be facilitated by using a primary current of very considerable frequency, since the electromotive force obtainable with a given length of conductor is proportionate to the frequency; but the frequency of the current is in a large measure arbitrary, for if the potential be sufficiently high and if the terminals of the coils be maintained at the proper altitudes the action described will take place, and a current will be transmitted through the elevated air strata, which will encounter little and possibly even less resistance than if conveyed through a copper wire of a practicable size. Accordingly the construction of the apparatus may be in many details greatly varied, but in order to enable any person skilled in the mechanical and electrical arts to utilize to advantage in the practical applications of my system the experience I have so far gained the following particulars of a model plant which has been long in use and which was constructed for the purpose of obtaining further data to be used in the carrying out of my invention on a large scale are given. The transmitting apparatus was in this case one of my electrical oscillators, which are transformers of a special type, now well known and characterized by the passage of oscillatory discharges of a condenser through the primary. The source G, forming one of the elements of the transmitter, was a condenser of a capacity of about four one-hundredths of a microfarad and was charged from a generator of alternating currents of fifty thousand volts pressure and discharged by means of a mechanically-operated break five thousand times per second through the primary C. The latter consisted of a single turn of stout stranded cable of inappreciable resistance and of an inductance of about eight thousand centimeters, the diameter of the loop being very nearly two hundred and forty-four centimeters. The total inductance of the primary circuit was approximately ten thousand centimeters, so that the primary circuit vibrated generally according to adjustment,

from two hundred and thirty thousand to two hundred and fifty thousand times per second. The high-tension coil A in the form of a flat spiral was composed of fifty turns of heavily-insulated cable No. 8 wound in one single layer, the turns beginning close to the primary loop and ending near its center. The outer end of the secondary or high-tension coil A was connected to the ground, as illustrated, while the free end was led to a terminal placed in the rarefied air stratum through which the energy was to be transmitted, which was contained in an insulating-tube of a length of fifty feet or more, within which a barometric pressure varying from about one hundred and twenty to one hundred and fifty millimeters was maintained by means of a mechanical suction-pump. The receiving-transformer was similarly proportioned, the ratio of conversion being the reciprocal of that of the transmitter, and the primary high-tension coil A' was connected, as illustrated, with the end near the low-tension coil C' to the ground and with the free end to a wire or plate likewise placed in the rarefied air stratum and at the distance named from the transmitting-terminal. The primary and secondary circuits in the transmitting apparatus being carefully synchronized, an electromotive force from two to four million volts and more was obtainable at the terminals of the secondary coil A, the discharge passing freely through the attenuated air stratum maintained at the above barometric pressures, and it was easy under these conditions to transmit with fair economy considerable amounts of energy, such as are of industrial moment, to the receiving apparatus for supplying from the secondary coil C' lamps L or kindred devices. The results were particularly satisfactory when the primary coil or system A', with its secondary C', was carefully adjusted, so as to vibrate in synchronism with the transmitting coil or system A C. I have, however, found no difficulty in producing with apparatus of substantially the same design and construction electromotive forces exceeding three or four times those before mentioned and have ascertained that by their means current impulses can be transmitted through much denser air strata. By the use of these I have also found it practicable to transmit notable amounts of energy through air strata not in direct contact with the transmitting and receiving terminals, but remote from them, the action of the impulses, in rendering conducting air of a density at which it normally behaves as an insulator, extending, as before remarked, to a considerable distance. The high electromotive force obtained at the terminals of coil or conductor A was, as will be seen, in the preceding instance, not so much due to a large ratio of transformation as to the joint effect of the capacities and inductances in the synchronized circuits, which effect is enhanced by a high frequency, and it will be obviously understood that if the latter be reduced a greater ratio of transformation should be resorted to, especially in cases in which it may be deemed of advantage to suppress as much as possible, and particularly in the transmitting coil A, the rise of pressure due to the above effect and to obtain the necessary electromotive force solely by a large transformation ratio.

While electromotive forces such as are produced by the apparatus just described may be sufficient for many purposes to which my system will or may be applied, I wish to state that I contemplate using in an industrial undertaking of this kind forces greatly in excess of these, and with my present knowledge and experience in this novel field I would estimate them to range from twenty to fifty million volts and possibly more. By the use of these much greater forces larger amounts of energy may be conveyed through the atmosphere to remote places or regions, and the distance of transmission may be thus extended practically without limit.

As to the elevation of the terminals D D', it is obvious that it will be determined by a number of things, as by the amount and quality of the work to be performed, by the local density and other conditions of the atmosphere, by the character of the surrounding country, and such considerations as may present themselves in individual instances. Thus if there be high mountains in the vicinity the terminals should be at a greater height, and generally they should always be, if practicable, at altitudes much greater than those of the highest objects near them in order to avoid as much as possible the loss by leakage. In some cases when small amounts of energy are required the high elevation of the terminals, and more particularly of the receiving-terminal D', may not be necessary, since, especially when the frequency of the currents is very high, a sufficient amount of energy may be collected at that terminal by electrostatic induction from the upper air strata, which are rendered conducting by the active terminal of the transmitter or through which the currents from the same are conveyed.

With reference to the facts which have been pointed out above it will be seen that the altitudes required for the transmission of considerable amounts of electrical energy in accordance with this method are such as are easily accessible and at which terminals can be safely maintained, as by the aid of captive balloons supplied continuously with gas from reservoirs and held in position securely by steel wires or by any other means, devices, or expedients, such as may be contrived and perfected by ingenious and skilled engineers. From my experiments and observations I conclude that with electromotive impulses not greatly exceeding fifteen or twenty million volts the energy of many thousands of horse-power may be transmitted over vast distances, measured by many hundreds

even thousands of miles, with terminals not more than thirty to thirty-five thousand feet above the level of the sea, and even this comparatively-small elevation will be required chiefly for reasons of economy, and, if desired, it may be considerably reduced, since by such means as have been described practically any potential that is desired may be obtained, the currents through the air strata may be rendered very small, whereby the loss in the transmission may be reduced.

It will be understood that the transmitting as well as the receiving coils, transformers, or other apparatus may be in some cases movable—as, for example, when they are carried by vessels floating in the air or by ships at sea. In such a case, or generally, the connection of one of the terminals of the high-tension coil or coils to the ground may not be permanent, but may be intermittently or inductively established, and any such or similar modifications I shall consider as within the scope of my invention.

While the description here given contemplates chiefly a method and system of energy transmission to a distance through the natural media for industrial purposes, the principles which I have herein disclosed and the apparatus which I have shown will obviously have many other valuable uses—as, for instance, when it is desired to transmit intelligible messages to great distances, or to illuminate upper strata of the air, or to produce, designedly, any useful changes in the condition of the atmosphere, or to manufacture from the gases of the same products, as nitric acid, fertilizing compounds, or the like, by the action of such current impulses, for all of which and for many other valuable purposes they are eminently suitable, and I do not wish to limit myself in this respect. Obviously, also, certain features of my invention here disclosed will be useful as disconnected from the method itself—as, for example, in other systems of energy transmission, for whatever purpose they may be intended, the transmitting and receiving transformers arranged and connected as illustrated, the feature of a transmitting and receiving coil or conductor, both connected to the ground and to an elevated terminal and adjusted so as to vibrate in synchronism, the proportioning of such conductors or coils, as above specified, the feature of a receiving-transformer with its primary connected to earth and to an elevated terminal and having the operative devices in its secondary, and other features or particulars such as have been described in this specification or will readily suggest themselves by a perusal of the same.

I do not claim in this application a transformer for developing or converting currents of high potential in the form herewith shown and described and with the two coils connected together, as and for the purpose set forth, having made these improvements the subject of a patent granted to me November 2, 1897, No. 593,138, nor do I claim herein the apparatus employed in carrying out the method of this application when such apparatus is specially constructed and arranged for securing the particular object sought in the present invention, as these last-named features are made the subject of an application filed as a division of this application on February 19, 1900, Serial No. 5,780.

What I now claim is—

1. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing at a generating-station a very high electrical pressure, causing thereby a propagation or flow of electrical energy, by conduction, through the earth and the air strata, and collecting or receiving at a distant point the electrical energy so propagated or caused to flow.

2. The method hereinbefore described of transmitting electrical energy, which consists in producing at a generating station a very high electrical pressure, conducting the current caused thereby to earth and to a terminal at an elevation at which the atmosphere serves as a conductor therefor, and collecting the current by a second elevated terminal at a distance from the first.

3. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, a sufficiently-high electromotive force to render elevated air strata conducting, causing thereby a propagation or flow of electrical energy, by conduction, through the air strata, and collecting or receiving at a point distant from the generating-station the electrical energy so propagated or caused to flow.

4. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator terminal elevated above the same, at a generating-station, a sufficiently-high electromotive force to render the air strata at or near the elevated terminal conducting, causing thereby a propagation or flow of electrical energy, by conduction, through the air strata, and collecting or receiving at a point distant from the generating-station the electrical energy so propagated or caused to flow.

5. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, electrical impulses of a sufficiently-high electromotive force to render elevated air strata conducting, causing thereby current impulses to pass, by conduction, through the air strata, and collecting or receiving at a point distant from the generating-station, the energy of the current impulses by means of a circuit synchronized with the impulses.

6. The method hereinbefore described of

DEFENDANT'S EXHIBIT Y-2

N° 20,981 A.D. 1896

Date of Application, 22nd Sept., 1896—Accepted, 21st Nov., 1896

COMPLETE SPECIFICATION.

[Communicated from abroad by Nikola Tesla, of 46 East Houston Street, New York, United States of America, Electrician.]

Improvements relating to the Production, Regulation, and Utilization of Electric Currents of High Frequency, and to Apparatus therefor.

I, Henry Harris Lake, of the Firm of Haseltine, Lake & Co., Patent Agents, 45 Southampton Buildings, in the County of Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention, subject of the present application, is embodied in certain improvements in methods of and apparatus for producing, regulating and utilizing electric currents of high frequency heretofore invented by Nikola Tesla, and described in British Letters Patent No. 8575, dated May 19, 1891. The method and apparatus referred to in said patent were devised for the purpose of converting, supplying and utilizing electrical energy in a form suited for the production of certain novel electrical phenomena which require currents of high potential and a higher frequency than can readily or even possibly, be developed by generators of the ordinary types or by such mechanical appliances as were theretofore known. The invention referred to was based upon the principle of charging a condenser or a circuit possessing capacity and discharging the same, generally through the primary of a transformer, the secondary of which constituted the source of working current, and under such conditions as to yield a vibratory or rapidly intermittent discharge current.

The present invention, while aiming to simplify and render more efficient the apparatus heretofore used, has for its object, primarily, to provide a means for converting such currents as are generally and most readily obtainable from the mains of ordinary systems of municipal distribution, into currents of the special character referred to, and to regulate or control and utilize such currents in a simple, economical and efficient manner. The improvements are illustrated herein in forms of apparatus adapted for use with existing circuits or systems, and which while constructed and operating on the same general principles are modified only as may be required by a direct or an alternating source of supply.

The apparatus by which the present improvements are carried out may be described in general terms as comprising a circuit from a given source of supply, in which is included or with which is connected any suitable device for making and breaking such circuit in the manner desired, a condenser arranged so as to be periodically charged by the said circuit through the instrumentality of the circuit controller, and a circuit, through which the condenser discharges, of such character that the discharge will take place in a series of rapidly recurring or intermittent impulses.

In the drawings which illustrate the invention,

Fig. 1 is a diagram of circuits and apparatus employed with a source of direct currents. Figs. 2 and 3 are modifications of the same.

Figs. 4, 5 and 6 illustrate the apparatus and circuit connections employed with a source of alternating current. Figs. 7, 8, 9, 10 are similar views illustrating the method of and apparatus for regulating the system.

[*Price 8d.*]

[illegible] illustrating a form of [illegible] controller [illegible] and manner of connecting up [illegible] the same.

[illegible] is to be employed for the purpose of converting a direct [illegible] comparatively low [illegible] high frequency, a device [illegible] [illegible] interposed in the circuit, in order that advantage may be taken of the discharge of high electro-motive force, which is manifested [illegible] for charging the condenser.

It will be apparent from a consideration of the conditions involved, that were [illegible] the condenser to be directly charged by the current from the source and then discharged into its local or discharging circuit, a very large capacity would [illegible] be required, but by the introduction into the charging circuit of a high self induction the current of high electro-motive force which is induced at each break of said circuit, furnishes the proper current for charging the condenser, which may therefore be small and inexpensive.

Figures 1 and 2 illustrate that part of the improvement which relates to the conversion of direct or continuous current. Referring to said figures, A designates any source of direct current. In any branch of the circuit from said source, such, for example, as would be formed by the conductors A^{11} A^{11} from the mains A^{1} A^{1}, and the conductors K K are placed self induction or choking coils B B and any proper form of circuit controlling device as C. This device in the present instance is shown as an ordinary metallic disk or cylinder with teeth or separated segments D, D, E E, of which one or more pairs as E E, diametrically opposite, are integral or in electrical contact with the body of the cylinder, so that when the controller is in the position in which the two brushes F, F^{1}, bear upon two of said segments E E, the circuit through the choking coils B B will be closed. The segments D, D, are insulated and while shown in the drawings as of substantially the same length of arc as the segments E E, this latter relation may be varied at will to regulate the periods of charging and discharging.

The controller is designed to be rotated by any proper device, such for example, as an electro-magnetic motor, as shown in Figure 2, receiving current either from the main source or elsewhere.

Around the controller C or in general having its terminals connected with the circuit on opposite sides of the point of interruption, is a condenser H, or a circuit of suitable capacity, and in series with the latter the primary K of a transformer, the secondary L of which constitutes the source of the currents of high frequency. L^{1} indicates the circuit from the secondary and may be regarded as the working circuit.

It will be observed that since the self induction of the circuit through which the condenser discharges, as well as the capacity of the condenser itself, may be given practically any desired value, the frequency of the discharge current may be adjusted at will.

In the operation of this apparatus the controller closes the charging circuit and then interrupts the same. When the break occurs the accumulated energy in the said circuit charges the condenser. Then while the charging circuit is again completed the condenser discharges through the primary K, by a succession of rapid impulses. These operations are maintained by the action of the controller.

A more convenient and simplified arrangement of the apparatus is shown in Figure 2. In this case the small motor G which drives the controller has its field coils M M^{1} in derivation to the main circuit, and the controller C and condenser H, are in parallel in the field circuit between the two coils. In such case the field coils M M^{1} take the place of the choking coils B.

In this arrangement, and in fact, generally, it is preferable to use two condensers or a condenser in two parts, and to arrange the primary coil of the transformer between them. The interruption of the field circuit of the motor should be so rapid as to permit only a partial demagnetization of the cores; these latter, moreover, should in this specific arrangement, be laminated.

In lieu of connecting the field coils of the motor only with the charging circuit

to raise the self induction therein, the motor may be connected in other ways, that is to say, its armature only may be connected with the circuit, or its field and armature coils may be in series and both connected with such circuit. This latter arrangement is illustrated in Figure 3, in which a terminal of the circuit A^{11} is connected to one of the binding posts of the motor [illegible] which the circuit is led through one field coil M, the brushes and commutator C^1 and the other field coil M^1, and thence to a brush F which rests upon the controller disk or cylinder C. The other terminal of the circuit connects with a second brush F^1 bearing on the controller, so that the current which passes through and operates the motor is periodically interrupted.

As an illustration of the various uses to which the apparatus may be put, the secondary L is shown in this figure as connected to two plates P, P, of any suitable character between which a current of air is maintained by a fan on the shaft of the motor G, for developing ozone or for similar purposes.

When the potential of the source of current periodically rises and falls, whether with reversals or not is immaterial, it is essential to economical operation that the intervals of interruption of the charging circuit should bear a definite time relation to the period of the current, in order that the effective potential of the impulses charging the condenser may be as high as possible. In case, therefore, an alternating or equivalent electromotive force be employed as the source of supply, a circuit controller is used which will interrupt the charging circuit at instants predetermined with reference to the variations of potential therein.

A convenient, and probably the most practicable means for accomplishing this is a synchronous motor connected with the source of supply and operating a circuit controller which first interrupts the charging current at or about the instant of highest intensity of each wave and then permits the condenser to discharge the energy stored in it, through its appropriate circuit. Such apparatus, which may be regarded as typical of the means for accomplishing this purpose, is illustrated in Figures 4, 5 and 6.

In Fig. 4, A^{11} A^{11} are the conductors taken from the mains of any alternating current generator A, and for raising the potential of such current a transformer is employed represented by the primary B and secondary B^1.

The circuit of the secondary includes the energizing coils of a synchronous motor G, and a circuit controller C fixed to the shaft of the motor.

An insulating arm O, stationary with respect to the motor shaft and adjustable with reference to the poles of the fixed magnets, carries two brushes F F^1 which bear upon the periphery of the disk C. With the parts thus arranged, the secondary circuit is completed through the coils of the motor whenever the two brushes rest upon the uninsulated segments of the disk, and interrupted through the motor at other times.

Such a motor, if properly constructed, in well understood ways, maintains very exact synchronism with the alternations of the source, and the arm O may, therefore, be adjusted to interrupt the current at any determined point of its waves. By the proper relations of insulated and conducting segments, and the motor poles, the current may be interrupted twice in each complete wave at or about the points of highest intensity.

In order that the energy stored in the motor circuit may be utilized at each break to charge the condenser H, the terminals of the latter are connected to the two brushes F F^1 or to points of the circuit adjacent thereto, so that when the circuit through the motor is interrupted the terminals of the motor circuit will be connected with the condenser. The discharge of the condenser takes place through the primary K, the circuit of which is completed simultaneously with the motor circuit and interrupted while the motor circuit is broken and the condenser being charged. The secondary impulses of high potential and great frequency are available for the operation of vacuum tubes P, single terminal lamps R, and other novel and useful purposes.

It is obvious that the supply current need not be alternating, provided it be

converted or transformed into an alternating current, before reaching the controller. For example, the present improvements are applicable to various forms of rotary transformers as is illustrated in Figs. 5 and 6.

G[1] designates a continuous current motor, here represented as having four field poles wound with coils E[11] in shunt to the armature. The line wires A[11] A[11] connect with the brushes *b b* bearing on the usual commutator.

On an extension of the motor shaft is a circuit controller composed of a cylinder, the surface of which is divided into four conducting segments *c*, and four insulating segments *d*, the former being diametrically connected in pairs as shown in Fig. 6.

Through the shaft run two insulated conductors *e e* from any two commutator segments ninety degrees apart, and these connect with the two pairs of segments *c*, respectively. With such arrangement, it is evident that any two adjacent segments *c c* become the terminals of an alternating current source, so that if two brushes F F[1] be applied to the periphery of the cylinder they will take off current during such portion of the wave as the width of segment and position of the brushes may determine. By adjusting the position of the brushes relatively to the cylinder, therefore, the alternating current delivered to the segments *c c* may be interrupted at any point of its waves.

While the brushes F F[1] are on the conducting segments the current which they collect stores energy in a circuit of high self-induction formed by the wires *f f*, self-induction coils S S, the conductors A[11] A[11], the brushes and commutator. When this circuit is interrupted by the brushes F F[1], passing onto the insulating segments of the controller, the high potential discharge of this circuit stores energy in the condensers H H which then discharge through the circuit of low self-induction containing the primary K. The secondary circuit contains any devices as P, P, for utilizing the current.

In some cases the energy delivered by the system may be readily and economically regulated. It is well known that every electric circuit, provided its ohmic resistance does not exceed certain definite limits, has a period of vibration of its own analogous to the period of vibration of a weighted spring. In order to alternately charge a given circuit of this character by periodic impulses impressed upon it and to discharge it most effectively, the frequency of the impressed impulses should bear a definite relation to the frequency of vibration possessed by the circuit itself. Moreover, for like reasons, the period of vibration of the discharge circuit should bear a similar relation to the impressed impulses or the period of the charging circuit. When the conditions are such that the general law of harmonic vibrations is followed, the circuits are said to be in resonance or in electro-magnetic synchronism, and this condition of the system is found to be highly advantageous.

In carrying out the invention, therefore, the electrical constants should be so adjusted that in normal operation the condition of resonance is approximately attained. To accomplish this, the number of impulses of current directed into the charging circuit per unit time is made equal to the period of the charging circuit itself, or, generally, to a harmonic thereof, and the same relations are maintained between the charging and discharge circuit. Any departure from this condition will result in a decreased output, and this fact is taken advantage of in regulating such output by varying the frequencies of the impulses or vibrations in the several circuits.

Inasmuch as the period of any given circuit depends upon the relations of its resistance, self-induction and capacity, a variation of any one or more of these may result in a variation in its period. There are, therefore, various ways in which the frequencies of vibration of the several circuits in the system may be varied, but the most practicable and efficient ways of accomplishing the desired result are the following:

(*a*) Varying the rate of the impressed impulses or those which are directed from the source of supply into the charging circuit, as by varying the speed of the commutator or other circuit controller.

(*b*) Varying the self-induction of the charging circuit.

(*c*) Varying the self-induction or capacity of the discharge circuit.

To regulate the output of a single circuit which has no vibration of its own, by merely varying its period would evidently require, for any extended range of regulation, a very wide range of variation of period. But in the system described, a very wide range of regulation of the output may be obtained by a very slight change of the frequency of one of the circuits when the above mentioned rules are observed.

Figs. 7, 8, 9 and 10 illustrate some of the more practicable means for effecting the regulation, as applied to a system deriving its energy from a source of direct currents.

In each of the figures A^{11} A^{11} designate the conductors of a supply circuit of continuous current, G a motor connected therewith in any of the usual ways, and operating a current controller C which serves to alternately close the supply circuit through the motor or through a self-induction coil, and to connect such motor circuit with a condenser H, the circuit of which contains a primary coil K, in proximity to which is a secondary coil L serving as the source of supply to the working circuit or that in which are connected up the devices P R for utilizing the current.

In order to secure the greatest efficiency in a system of this kind, it is essential, as before stated, that the circuits, which mainly as a matter of convenience are designated as the charging and the discharge circuits, should be approximately in resonance or electro-magnetic synchronism. Moreover, in order to obtain the greatest output from a given apparatus of this kind it is desirable to maintain as high a frequency as possible.

The electrical conditions, which are now well understood, having been adjusted to secure, as far as practical considerations will permit, these results, the regulation of the system is effected by adjusting its elements so as to depart in a greater or less degree from the above conditions with a corresponding variation of output. For example, as in Figure 7 the speed of the motor, and consequently of the controller, may be varied in any suitable manner, as by means of a rheostat R^1 in a shunt to such motor, or by shifting the position of the brushes on the main commutator of the motor or otherwise. A very slight variation in this respect by disturbing the relations between the rate of impressed impulses and the vibration of the circuit of high self-induction into which they are directed, causes a marked departure from the condition of resonance and a corresponding reduction in the amount of energy delivered by the impressed impulses to the apparatus.

A similar result may be secured by modifying any of the constants of the local circuits as above indicated. For example, in Figure 8 the choking coil B is shown as provided with an adjustable core N^1, by the movement of which into and out of the coil the self-induction, and consequently the period of the circuit containing such coil, may be varied.

As an example of the way in which the discharge circuit or that into which the condenser discharges, may be modified to produce the same result, there is shown in Figure 9 an adjustable self-induction coil R^{11} in the circuit with the condenser, by the adjustment of which coil the period of vibration of such circuit may be changed.

The same result would be secured by varying the capacity of the condenser, but if the condenser were of relatively large capacity this might be an objectionable plan, and a more practicable method is to employ a variable condenser in the secondary or working circuit, as shown in Figure 10. As the potential in this circuit is raised to a high degree, a condenser of very small capacity may be employed, and if the two circuits, primary and secondary, are very intimately and closely connected, the variation of capacity in the secondary is similar in its effects to the variation of the capacity of the condenser in the primary. As a means well adapted for this purpose two metallic plates S^1 S^1 adjustable to and from each other and constituting the two armatures of the condenser are shown.

The description of the means of regulation is confined herein to a source of supply of direct current, for to such it more particularly applies, but it will be understood that if the system be supplied by periodic impulses from any source which will effect the same results, the regulation of the system may be effected by the method herein described.

The circuit controller or the device which ensures the proper charging and discharging of the condenser may be of any construction that will perform the functions required of it. In illustration of the principle of construction and mode of operation, reference has been made only to forms of mechanism that make and break metallic contacts, but there need be no actual metallic contact, if provision be made for the passage of a spark between separated conductors. Such a device is illustrated in Figs. 11 to 15.

A designates, in Fig. 11, a generator having a commutator a^1 and brushes a^{11} bearing thereon, and also collecting rings b^{11}, b^{11}, from which an alternating current is taken by brushes b^1 in the well understood manner.

The circuit controller is mounted, in part, on an extension of the shaft c^1 of the generator, and in part on the frame of the same, or on a stationary sleeve surrounding the shaft. Its construction, in detail, is as follows:—

e^1 is a metal plate with a central hub e^{11} which is keyed or clamped to the shaft c^1. The plate is formed with segmental extensions corresponding in number to the waves of current which the generator delivers. These segments are preferably cut away, leaving only rims or frames, to one of the radial sides of which are secured bent metal plates i which serve as vanes to maintain a circulation of air when the device is in operation.

The segmental disk and vanes are contained within a close insulated box or case j mounted on the bearing of the generator, or in any other proper way, but so as to be capable of angular adjustment around the shaft. To facilitate such adjustment, a screw rod f^1, provided with a knob or handle, is shown as passing through the wall of the box. The latter may be adjusted by this rod, and when in proper position may be held therein by screwing the rod down into a depression in the sleeve or bearing as shown in Fig. 11.

Air passages g g are provided at opposite ends of the box through which air is maintained in circulation by the action of the vanes.

Through the sides of the box f, and through insulating gaskets h, when the material of the box is not a sufficiently good insulator, extend metallic terminal plugs l, l, with their ends in the plane of the conducting segmental disk e^1 and adjustable radially towards and from the edges of the segments.

Devices of this character are employed in the manner illustrated in Fig. 13.

A, in this figure, represents any source of alternating current, the potential of which is raised by a transformer of which B is the primary and B^1 the secondary.

The ends of the secondary circuit s are connected to the terminal plugs l, l, of an apparatus similar to that of Figures 11 and 12, and having segments rotating in synchronism with the alternations of the current source, preferably, as above described, by being mounted on the shaft of the generator, when the conditions so permit.

The plugs l, l, are then adjusted radially so as to approach more or less the path of the outer edges of the segmental disk, and so that during the passage of each segment in front of a plug a spark will pass between them, which completes the secondary circuit, s. The box, or the support for the plugs l, is adjusted angularly so as to bring the plugs and segments into proximity at the desired instants with reference to any phase of the current wave in the secondary circuit, and fixed in position in any proper manner.

To the plugs l, l, are also connected the terminals of a condenser or condensers, so that at the instant of the rupture of the secondary circuit s by the cessation of the sparks the energy accumulated in such circuit will rush into, and charge, the condenser.

A path of low self-induction and resistance, including a primary K of a few

turns, is provided to receive the discharge of the condenser, when the circuit *s* is again completed by the passage of sparks, the discharge being manifested as a succession of extremely rapid impulses.

By means of this apparatus effects of a novel and useful character are obtainable, but to still further increase the efficiency of the discharge or working current, there may be in some instances provided a means for further breaking up the individual sparks themselves. A device for this purpose is shown in Figures 14 and 15.

The box or case *f* in these figures is fixedly secured to the frame or bearing of the generator or motor which rotates the circuit controller in synchronism with the alternating source. Within said box is a disk e^1 fixed to the shaft c^1 with projections d^1 extending from its edge parallel with the axis of the shaft. A similar disk e^1 on a spindle d^{11} in face of the first is mounted in a bearing in the end of the box *f* with a capability of rotary adjustment.

The ends of the projections d^1 are deeply serrated or several pins or narrow projections placed side by side, as shown in Fig. 14, so that as those of the opposite disks pass each other a rapid succession of sparks will pass from the projections of one disk to those of the other.

The invention is not limited to the precise devices or forms of the devices shown and described. For example, when the source of supply is a circuit of high self-induction no special choking coils or the like need be employed. So, too, the condenser as a distinctive apparatus may be dispensed with when the capacity of its circuit is sufficiently great to accomplish the desired result. The circuit controller may, as already explained, be very greatly modified and varied in construction and principle of operation without departure from the invention.

In the illustrations given of the circuit controller, the contacts and insulating spaces are arranged for charging and discharging a single condenser, but it is obvious that a single motor and circuit controller may be used to operate more than one condenser, by charging one while discharging the other or others.

Having now particularly described and ascertained the nature of the said invention and in what manner the same is to be performed, as communicated to me by my foreign correspondent, I declare that what I claim is:—

1. The apparatus herein described for converting electric currents of the kind generally obtainable from municipal systems of electric distribution, into currents of high frequency, comprising in combination a circuit of high self-induction, a circuit controller adapted to make and break such circuit, a condenser into which the said circuit discharges when interrupted, and a transformer through the primary of which the condenser discharges, as set forth.

2. The combination with a circuit of high self-induction and means for making and breaking the same, of a condenser around the point of interruption in the said circuit, and a transformer the primary of which is in the condenser circuit, as described.

3. The combination with a circuit having a high self-induction, of a circuit controller for making and breaking said circuit, a motor for driving the controller, a condenser in a circuit connected with the first around the point of interruption therein, and a transformer the primary of which is in circuit with the condenser, as set forth.

4. The combination with an electric circuit of a controller for making and breaking the same, a motor included in or connected with said circuit so as to increase its self-induction and driving the said controller, a condenser in a circuit around the controller, and a transformer through the primary of which the condenser discharges, as set forth.

5. The combination with a circuit of direct current, of a controller for making and breaking the same, a motor having its field or armature coils or both included in said circuit and driving said controller, a condenser connected

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with the circuit around the point of interruption therein, and a transformer, the primary of which is in the discharge circuit of the condenser, as set forth.

6. The method herein described of converting alternating currents of relatively low frequency into currents of high frequency, which consists in charging a condenser by such currents of low frequency during determinate intervals of each wave of said current, and discharging the condenser through a circuit of such character as to produce therein a rapid succession of impulses, as set forth.

7. The combination with a source of alternating current, a condenser, a circuit controller adapted to direct the current during determinate intervals of each wave into the condenser for charging the same, and a circuit into which the condenser discharges, as set forth.

8. The combination with a source of alternating current, a synchronous motor operated thereby, a circuit controller operated by the motor and adapted to interrupt the circuit through the motor at determinate points in each wave, a condenser connected with the motor circuit and adapted on the interruption of the same to receive the energy stored therein, and a circuit into which the condenser discharges, as set forth.

9. The combination with a source of alternating current, a charging circuit in which the energy of said current is stored, a circuit controller adapted to interrupt the charging circuit at determinate points in each wave, a condenser for receiving, on the interruption of the charging circuit, the energy accumulated therein, and a circuit into which the condenser discharges when connected therewith by the circuit controller, as set forth.

10. The method of regulating the energy delivered by a system for the production of high frequency currents, and comprising a supply circuit, a condenser, a circuit through which the same discharges, and means for controlling the charging of the condenser by the supply circuit and the discharging of the same, the said method consisting in varying the relations of the frequencies of the impulses in the circuits comprising the system, as set forth.

11. The method of regulating the energy delivered by a system for the production of high frequency currents comprising a supply circuit of direct currents, a condenser adapted to be charged by the supply circuit and to discharge through another circuit, the said method consisting in varying the frequency of the impulses of current from the supply circuit, as set forth.

12. The method of producing and regulating electric currents of high frequency which consists in directing impulses from a supply circuit into a charging circuit of high self-induction, charging a condenser by the accumulated energy of such charging circuit, discharging the condenser through a circuit of low self-induction, raising the potential of the condenser discharge and varying the relations of the frequencies of the electrical impulses in the said circuits, as set forth.

13. The combination with a source of current, of a condenser adapted to be charged thereby, a circuit into which the condenser discharges in a series of rapid impulses, and a circuit controller for effecting the charging and discharge of said condenser, composed of conductors movable into and out of proximity with each other, whereby a spark may be maintained between them and the circuit closed thereby during determined intervals, as set forth.

14. The combination with a source of alternating current, of a condenser adapted to be charged thereby, a circuit into which the condenser discharges in a series of rapid impulses, and a circuit controller for effecting the charging and discharge of said condenser composed of conductors movable into and out of proximity with each other in synchronism with the alternations of the source, as set forth.

15. A circuit controller for systems of the kind described, comprising in combination a pair of angularly adjustable terminals and two or more rotating conductors mounted to pass in proximity to the said terminals, as set forth.

16. A circuit controller for systems of the kind described, comprising in

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combination two sets of conductors, one capable of rotation and the other of angular adjustment whereby they may be brought into and out of proximity to each other at determinate points and one or both being subdivided so as to present a group of conducting points, as set forth.

Dated this 22nd day of September 1896.

HASELTINE, LAKE & Co.,
45 Southampton Buildings, London, W.C., Agents for the Applicant.

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(2 SHEETS)
SHEET 1

Fig.1

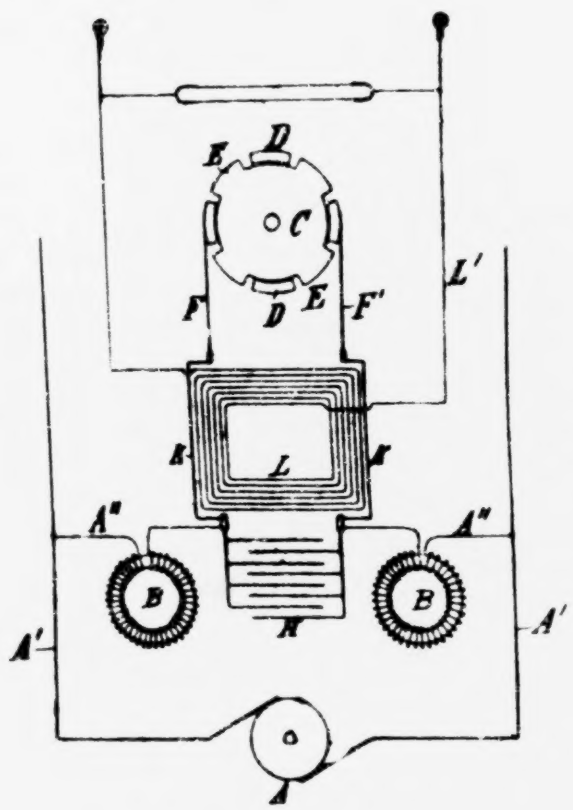


Fig. 2

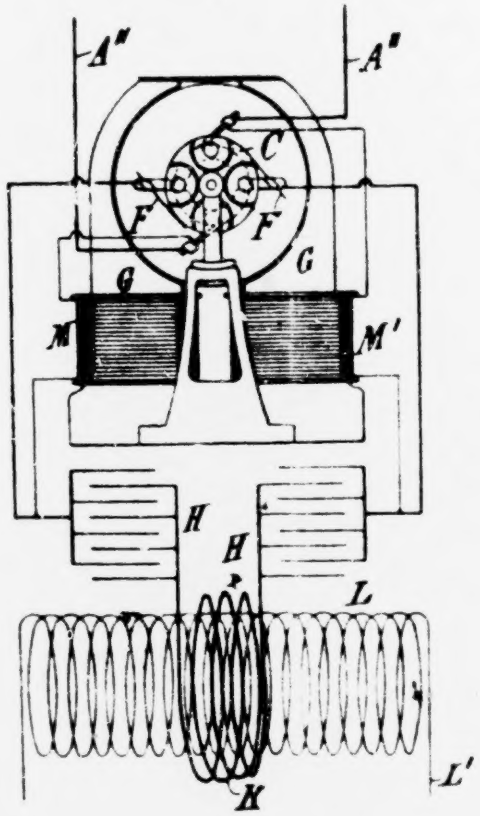


Fig. 3

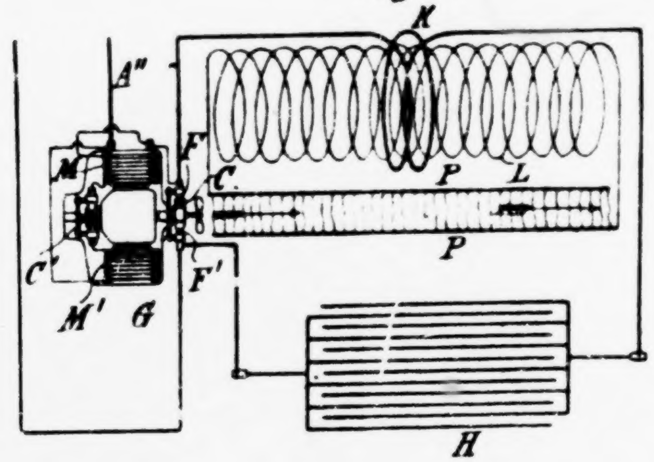


Fig. 9

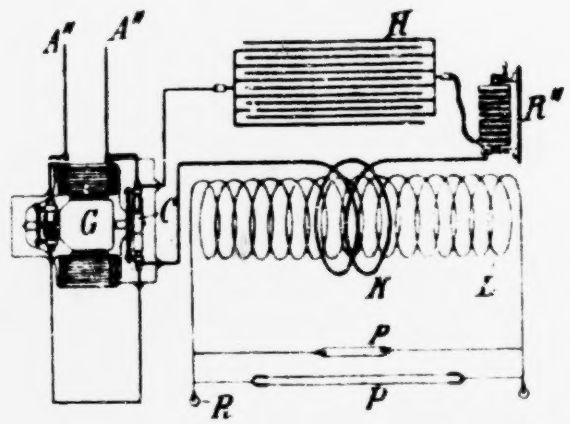


Fig. 7

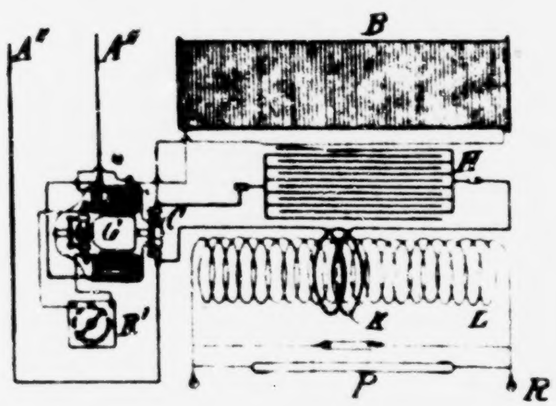


Fig. 8

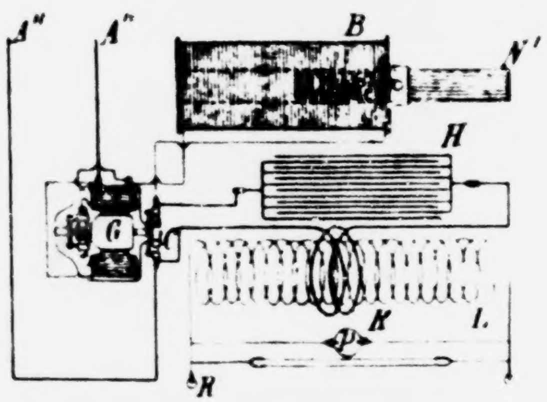
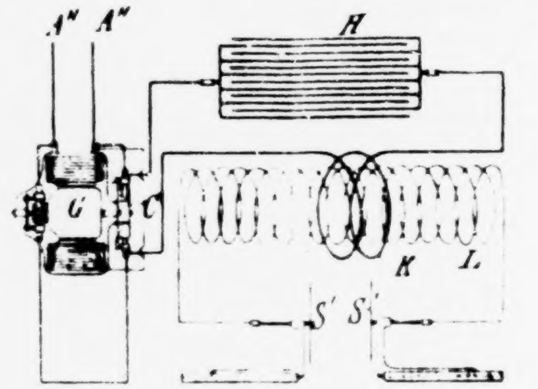


Fig. 10



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A.D. 1896. Sep. 22. N° 20,981.
LAKE'S COMPLETE SPECIFICATION.

Fig. 4

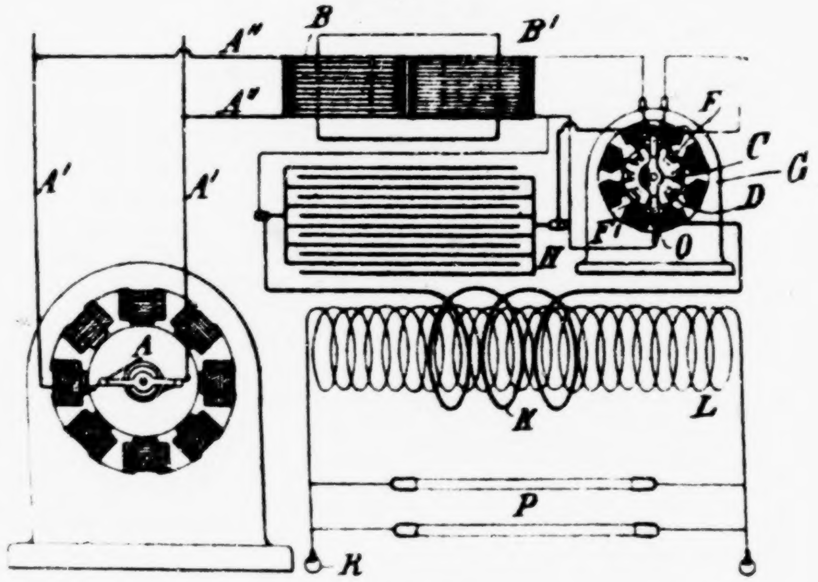

Fig. 5

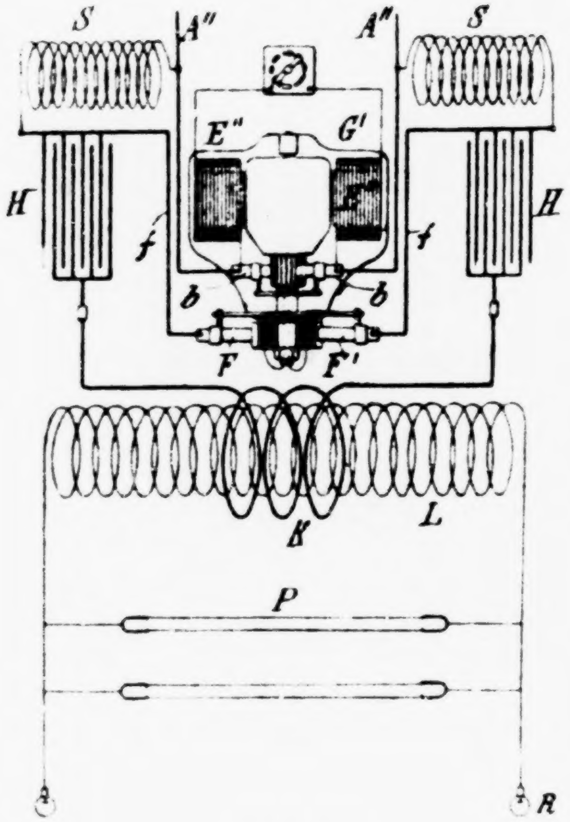

Fig. 6

Fig. 11

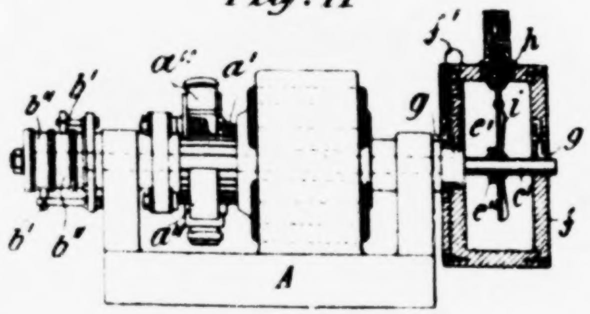

Fig. 12

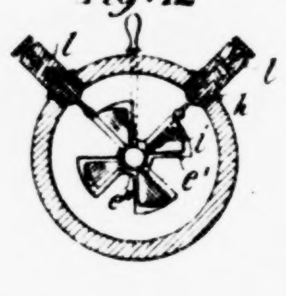

Fig. 13

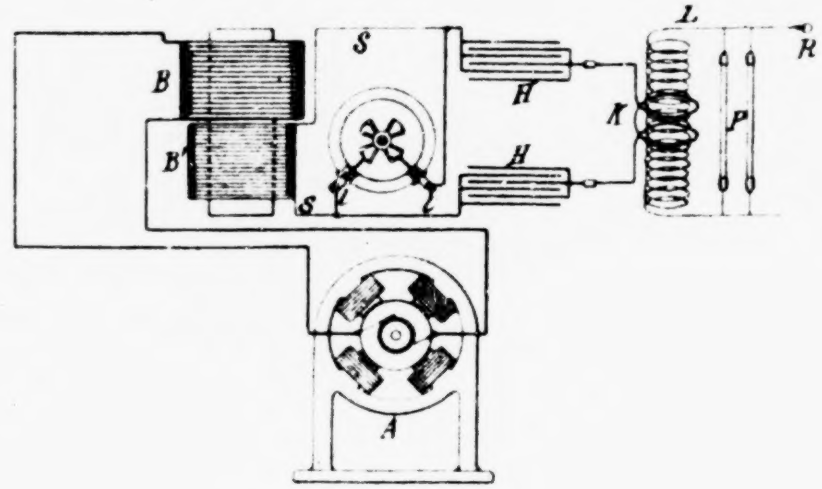

Fig. 14

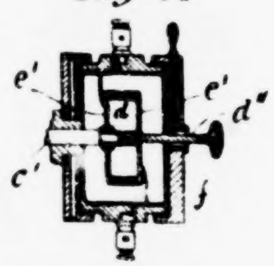

Fig. 15

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Malby & Sons, Photo-litho.

vibrations is that their potential and amplitude, and thereby the energy transmitted is more easily increased. When the Hertzian waves are used there is a certain length of spark which must not be exceeded if the circuit is required to excite vibrations; otherwise the vibrations would be damped too much, the constraint of the system giving way gradually instead of suddenly, but this means that the effective potential is limited, which if lower oscillations are used either does not occur, or can be very easily avoided.

I have found by experiments that the oscillations produced by the discharge of Leyden jars of usual size in a circuit having moderate self-induction, are very convenient for the purpose of transmitting signals, and the experiments also shew that with an equal expenditure of energy in the transmitting circuit it is preferable to use the slower vibrations.

Dated this 26th day of January 1899.

W. P. THOMPSON & Co.,
322, High Holborn, London, W.C. Patent Agents for the Applicant.

COMPLETE SPECIFICATION.

Improvements relating to the Transmission of Electric Telegraph Signals without Connecting Wires.

I, Ferdinand Braun, Professor and Doctor of Philosophy, of No. 1, Universität Strasse, Strassburg, in the Province of Alsace, German Empire, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

My invention relates to the transmission of electric signals without connecting wires, and comprises the improvements hereinafter indicated.

The electrical vibrations may be classified into three groups.

The first group includes vibrations which are created by the relative mechanical movement of magnets and coils. These may be called electromagnetic vibrations, and are exemplified in the well known ordinary alternating currents, as used for electric light and transmission of power. Their frequency will obviously be limited by the physical conditions of machinery.

A second group of electrical vibrations has been investigated by Feddersen, and others, and these vibrations consist of oscillations which are produced by the discharge of Leyden jars with or without induction coils in circuit. The frequency of these oscillations is considerably higher than the frequency of the electromagnetic vibrations above referred to.

Third group of vibrations is that first studied by the late Dr. Hertz, and known now as Hertzian waves, and in the production of these the capacity in the circuit is not produced by means of Leyden jars and special induction coils but the capacity and induction of ordinary conductors are used.

Hitherto the attention of inventors has been principally confined to Hertzian waves for the transmission of signals between two circuits without the use of connecting wires and one object has been to increase the frequency of these waves as much as possible in order to obtain propagation in a line as straight as possible. This is exemplified by the use of the Righi transmitter. For the transmission of signals in this manner it is essential, however, that the transmitting and receiving circuits should be, so to speak, visible to each other as stated by Dr. Hertz in one of his earlier papers concerning the transmission of electric waves, and by Professor Slaby's experiments it has been shewn that various material

3621

objects, such as sails, smoke, trees, buildings and the like, interposed between the circuits, weaken or in some cases entirely prevent communication between the same.

My invention is partially intended to obviate this inconvenience, and I do this by making use of electrical oscillations belonging to the second group above mentioned, and which have only a small frequency compared with the frequencies hitherto adopted. By this means, owing to the length of the waves, these latter are able to pass through conductors if these are of moderate thickness only. Furthermore, obstacles in the path of the waves will not project such sharply defined shadows, the waves passing round them in a manner similar to that in which sound waves pass round obstacles. Another and perhaps even more important advantage in using slower vibrations is that their potential and amplitude, and thereby the energy transmitted, is more easily increased. When the Hertzian waves are used there is a certain length of spark which must not be exceeded if the circuit is required to excite vibrations, otherwise the vibrations would be damped too much, the constraint of the system giving way gradually instead of suddenly, but this means that the effective potential is limited, which if slower oscillations are used either does not occur or can be very easily avoided.

I have found by experiments that the oscillations produced by the discharge of Leyden jars of usual size in a circuit having moderate self-induction, are very convenient for the purpose of transmitting signals, and the experiments also shew that with an equal expenditure of energy in the transmitting circuit it is preferable to use the slower vibrations.

The Leyden jar or whatever other apparatus used for the production of the electric impulses is connected with the spark gap of a Rhumkorff apparatus or a Wimshurst influence machine and provided with the well known vertical sending wire preferably of considerable length. In the receiving station the ordinary arrangement may also be used for the vertical receiving wire, the coherer, local battery and signalling device, such as Morse or the like.

In order that the invention may be clearly understood I have shown in the accompanying drawings by way of example some arrangements of circuits for transmitting signals by means of the electric oscillations above described.

In Figure 1 a Leyden jar indicated at F has its inner and outer coatings connected through the air gap *a*, a coil P of small self-induction being included in the circuit. The inner coating is connected to the transmitting wire M. The jar is charged in the usual manner by means of an influence machine, inductorium or other suitable means.

In Figure 2 a secondary coil S is provided communicating with the transmitting wire M so that the oscillatory currents in the coil P are transformed into currents at an increased potential.

In place of one jar two or more can be used connected in parallel or in series. Figure 3 for example shews two jars arranged in series, or as commonly called in "cascade."

Figure 4 shows an arrangement similar to Figure 3, but in which the current is transformed, a secondary coil S being connected with the transmitting wire M.

The invention is not limited to the precise arrangements or circuits shown in the drawings, as these can be varied very considerably, and electrical oscillations of a low frequency suitable for transmitting signals according to my invention can be produced in various other ways.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. The improvement in the transmission of electrical signals without connecting wires, which consists in using electrical vibrations of comparatively low frequency such as are produced by the discharge of Leyden jars, either with or without induction coils or circuits, substantially as described.

2. For the system of wireless transmission of electrical signals the combination with a transmitting device, consisting of a spark producer, condensers and vertical sending wire, of a receiving device, consisting of a receiving wire, local battery, coherer and signalling apparatus, substantially as described.

Dated the 23rd day of October 1899.

W. P. THOMPSON & Co.,
Of London, Liverpool, Manchester, and Birmingham.

Redhill: Printed for Her Majesty's Stationery Office, by Malcomson & Co., Ltd.—1900.

A.D. 1899. Jan 26. N° 1862.

BRAUN'S Complete Specification. 1 SHEET

Fig. 1.

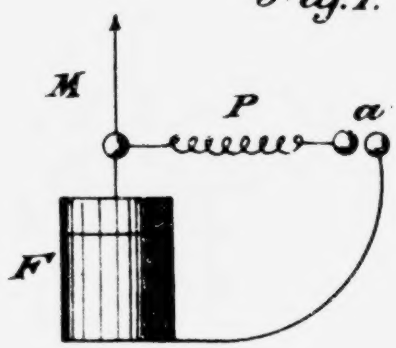


Fig. 2.

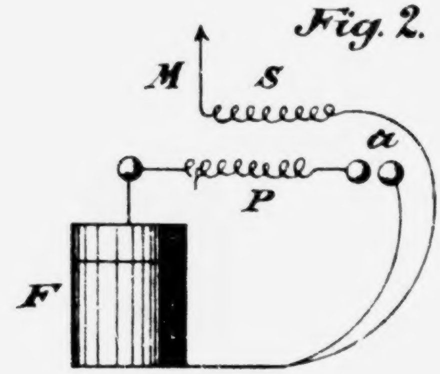


Fig. 3.

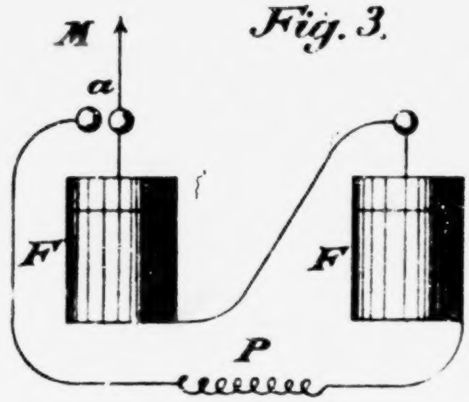
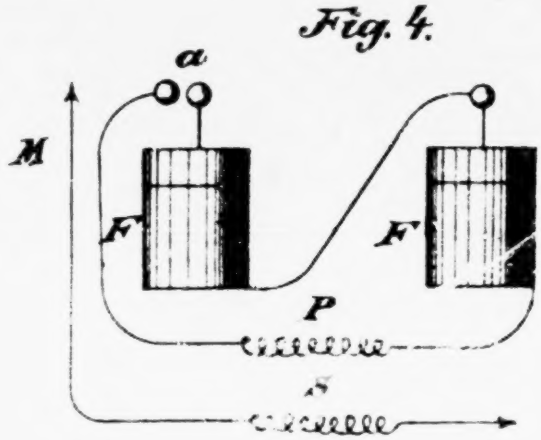


Fig. 4.



This Drawing is a reproduction of the Original on a reduced scale

3623A

DEFENDANT'S EXHIBIT A-3

intercepting wires a length of wire or a device acting by induction or capacity, or both, in such a way that it produces a difference of path of half a wave length.

Both arrangements may also be combined.

It is also possible to make the transmitter out of two crossed systems insulated from each other and to form the receiver in the same way taking care of favourable conditions of capacity. The horizontally polarised waves pass through the vertical wires or rods and *vice versa*. The advantage lies in being able to regulate the capacity and in the symmetry of arrangement and compactness within a small space which renders possible a metallic protection against unexpected interruptions.

The current collected from the frame can also be conveyed to a small primary coil and transformed in a secondary coil to greater potential, and then the coherer be excited thereby.

Moreover two metal balls, which are in so intimate contact with each other as the particles of a coherer can be inserted in the intercepting wire the quick oscillations produced thereby are conducted to the coherer. This may be of advantage in dealing with very slow waves.

The transmitter and receiver, or one of them, can also consist of plate coils or of solenoids of the usual form.

Dated the 14th day of June 1899.

W. P. THOMPSON & Co.,
322, High Holborn, London, W.C., Patent Agents for the Applicant.

COMPLETE SPECIFICATION.

Improvements in Wireless Telegraphy.

I, FERDINAND BRAUN, Professor and Doctor of Philosophy, of No. 1, Universitat Strasse, Strasburg, in the Alsace, German Empire, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

It has already been proposed in wireless telegraphy to attach a large metal plate to the receiving wire with the object of strengthening the action thereby. But in the same degree as (under the most favourable conditions) the absolute quantity of electricity intercepted is increased, the surface to be charged is also correspondingly increased, so that the increase of potential on which the excitation of the coherer specially depends is not thereby arrived at. In conformity with this conclusion experiments have shown that this arrangement is practically useless.

The following arrangement is intended to obviate this defect.

This invention is shown by the figures (1—10), which are diagrams of the arrangements and the electrical connections, similar reference letters being provided for similar parts.

A number of parallel wires, as thin as possible, a^1, a^2, a^3 and so forth are stretched as to form a grating parallel to the direction of the electric vibrations of the transmitter; they are connected to the coherer C by means of a common connecting wire. Herein use is made of the discovery that the electro-static lines of force as well as the dielectric displacement currents when in the neighbourhood of conductors tend to come nearer to one another. In this manner practically the entire electric energy of the induction falling on the surface, is intercepted, whilst the capacity is very small. The potentials

are therefore high and the reaction favourable, as proved by experiment. The wire can of course be distributed as on a cylindrical surface.

Fig. 2 shews a symmetrical arrangement, K is a condenser, C the coherer, the action of these elements being so well known as to need no further description.

The electro-dynamic reactions which occur in the single wires are hereby obviously increased only with regard to the free charges thus produced and as soon as their quantity is sufficient for the capacity of the coherer and the neighbouring surface to be charged, then practically the limit of the reaction is reached.

In order also to sum up the induced electro-motive forces, the wires must be connected in series. But doing so, as indicated in Fig. 3, then one would come to no result because, if in the front wires a^1, a^2, a^3 and so forth turned towards the transmitter, currents in the upward direction were induced then the same amount of potential would be produced in the wires a^1, a^2, a^3 and so forth, on the other side of the grating but in the opposite sense, and therefore the windings would neutralise one another. The following arrangement (Fig. 4) avoids this defect. Between the front and back wires and insulated from them a sheet of metal is inserted. This protects the back wires from direct induction so as to to make them serve essentially only as conducting wires in order to sum up the electro-motive forces induced in the front side. The same object can be attained by protecting the leading off wires by surrounding metal (say in the shape of a tube).

The metal sheet may in practise be replaced by wire gauze and there is even some action if it is quite absent as the front wires themselves partially screen the back ones if suitably placed.

Finally the same object may be attained as indicated in Fig. 5. When between front and back intercepting wires a length of wire is operatively connected by means of induction or capacity or both, which wire is of such a length as to produce a difference of course of half a wave length.

Fig. 6 shews a combination of the two arrangements.

Fig. 7 a symmetrical arrangement; K is a condenser C the corresponding tube.

It is also possible to make the transmitter out of two systems of grating arranged crosswise and insulated from each other (Fig. 8) and to form the receiver in the same way having regard to favourable conditions of capacity. The horizontally polarised waves pass through the vertical wires or rods and *vice versa*. The advantage lies in the possibility of regulating the capacity and the symmetry of arrangement and compactness within a small space which renders possible a metallic protection against unexpected disturbance.

The current collected from the frame can also be conveyed to a small primary coil I and transformed in a secondary coil II to greater potential, and then the coherer be excited thereby.

Moreover two metal balls S^1, S^2 can be inserted in the intercepting wire especially in dealing with the interior of a coherer, and the quick oscillations produced thereby are conducted to the coherer.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. An intercepting apparatus for telegraphy by electrical waves consisting of a system of parallel wires for the incoming electrical vibrations, which wires may be connected either in parallel or in series substantially as described.

2. The special arrangement of arranging the wires in two planes lying one behind the other between which planes is placed a metal plate or a lattice, substantially as described.

3. Connections between the wires devised by means of resistance, capacity or

self induction to displace the phase of the front set of wires half a wave length against the back set substantially as described

4 Two gratings of wire crossing each other at right angles and one lying behind the other, substantially as described.

Dated the 13th day of March 1900.

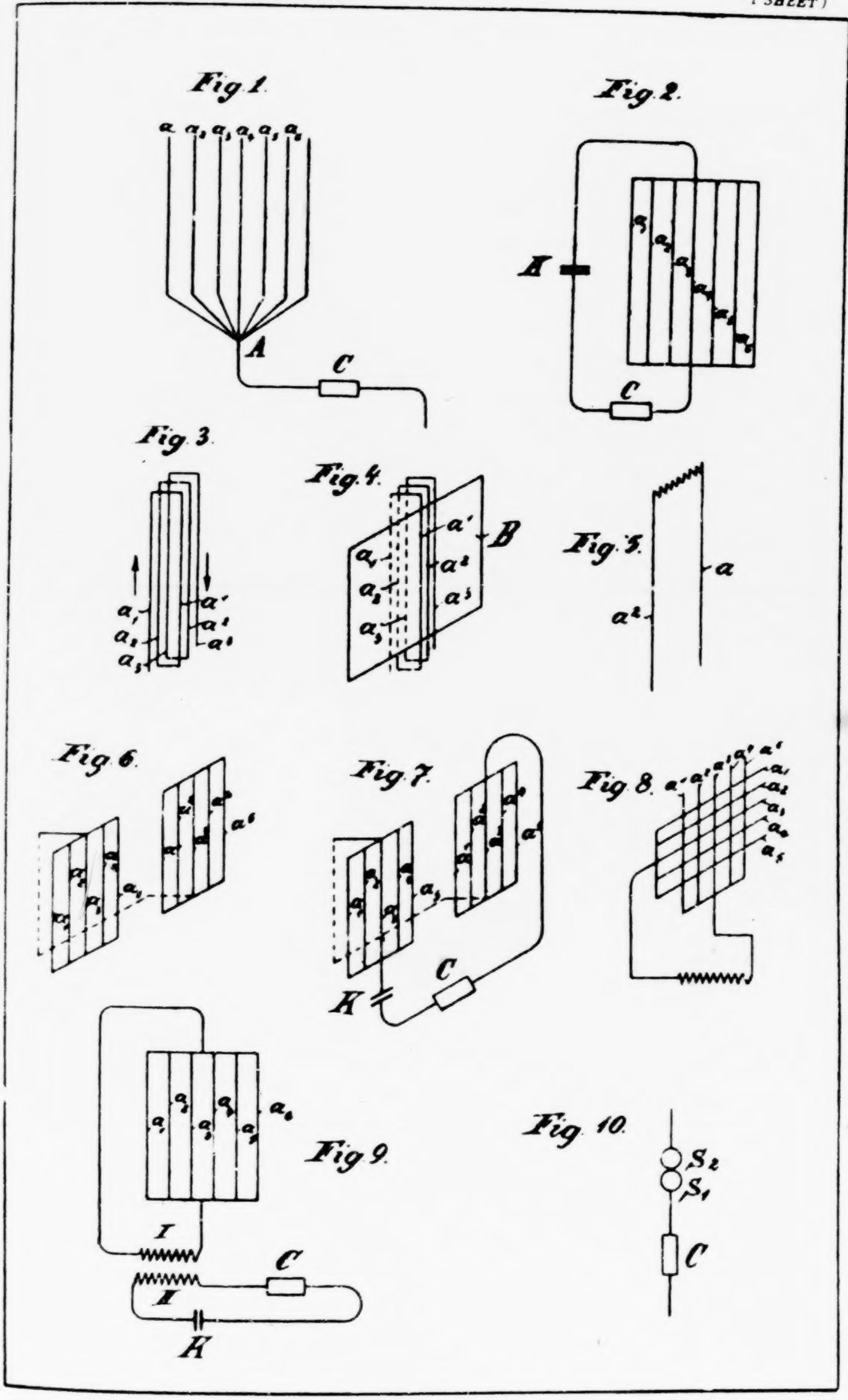
W. P. THOMPSON & Co.,
Of London, Liverpool, Manchester and Birmingham.

Redhill: Printed for Her Majesty's Stationery Office, by Malcomson & Co., Ltd.—1900.

A.D. 1899. June 14. N° 12,420.

BRAUN'S COMPLETE SPECIFICATION.

(1 SHEET)



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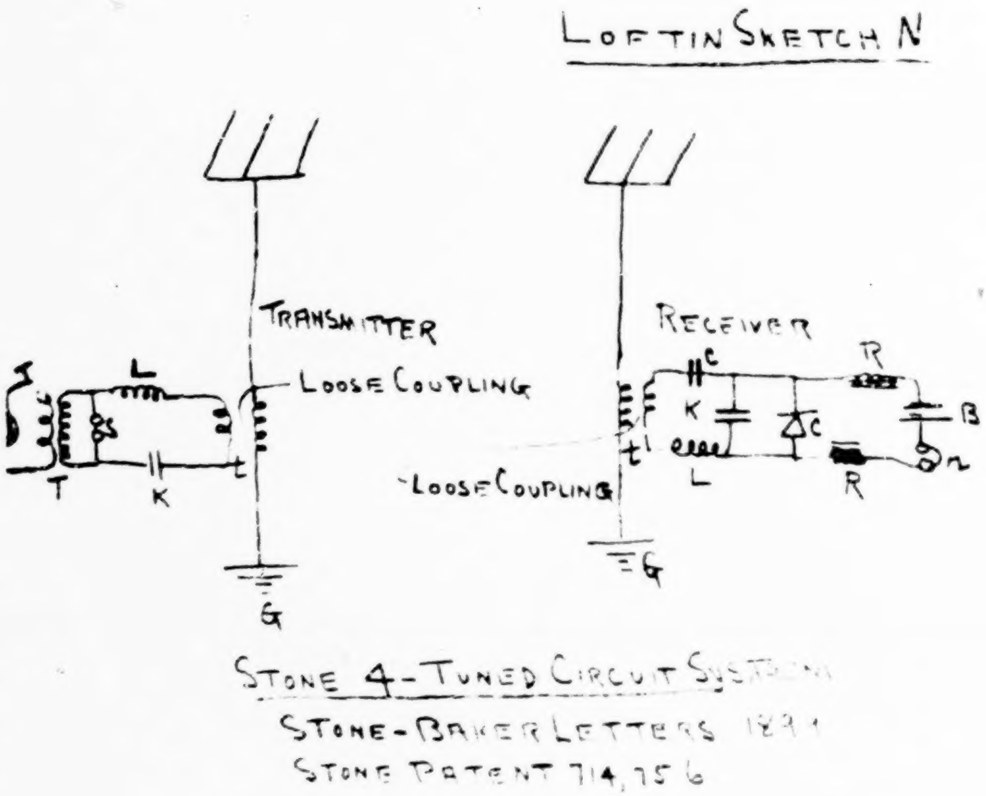
Malby & Sons Photo-Litho

DEFENDANT'S EXHIBIT B-3



Loftin Sketch O

Quenched Gap System.

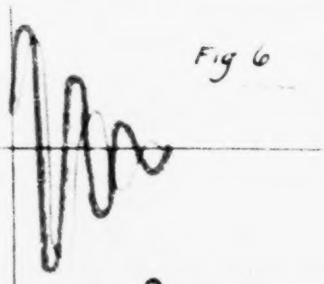


Fig 6

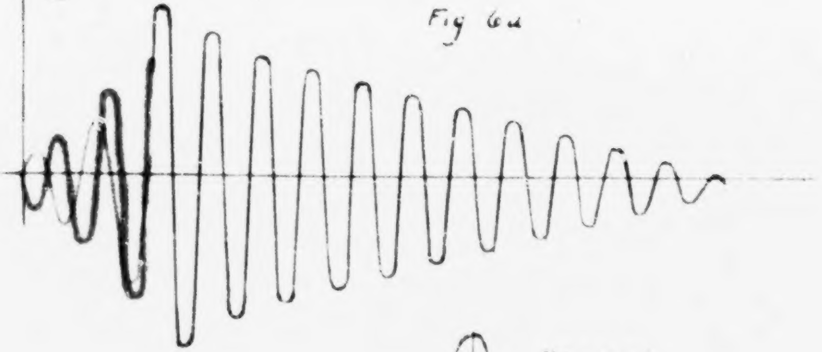


Fig 6a

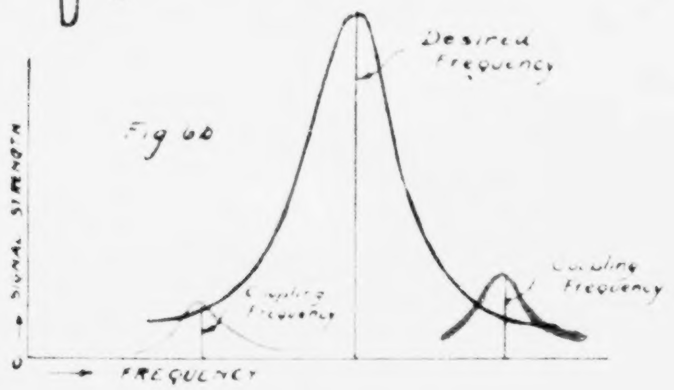


Fig 6b

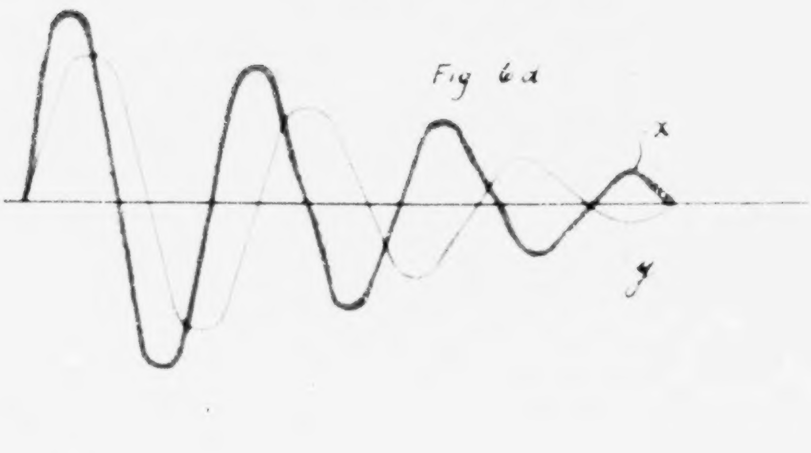


Fig 6d

DEFENDANT'S EXHIBIT E-3

(Defendant's Exhibit No. 1, Baker Deposition)

Boston, July 22, 1898.

Mr. John Stone Stone,
Phillips Building,
Boston, Mass.

My dear Stone:-

June 20th

Your letters of July 18th and ~~20th~~ last were received in due course, and have been read with great interest. The "selective" methods of space telegraphy therein described I believe I understand sufficiently to set up and operate them.

Allow me to add that this specialization of the work which Marconi's experiments to date leave in rather primitive condition, is very important, and should be prosecuted without delay by way of further development, and protection by letters-patent.

Yours very cordially,

Joseph B. Baker

DEFENDANT'S EXHIBIT F-3

June 30th 1899

My dear Baker:-

The chief limitation to the utility of the vertical wire space telegraphy system is that the radiations emanate in all directions from the transmitting wire so that within the sphere of influence of one vertical wire, all other vertical wire stations are affected by the signals sent from this wire and may not only receive the signals sent from it, but will be interfered with by it in the process of receiving signals from any other vertical wire station from which they may be attempting to receive a communication.

This difficulty may be overcome by using transmitting wires giving forth simple harmonic signal waves and receiving these signal waves at stations only capable of receiving simple harmonic signal waves.

In the existing vertical wire stations, the waves sent out and the waves received are complex harmonic waves owing to the fact that the vertical wires are not simple resonators but are capable, upon having their electrical equilibrium abruptly disturbed, of developing oscillations of a

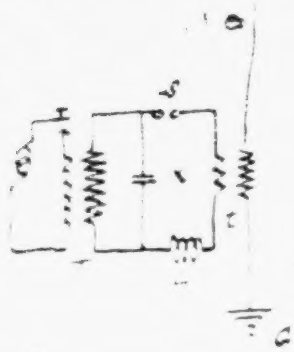
considerable number of different frequencies and also are capable of responding more or less powerfully to a correspondingly large number of different frequencies.

Instead of utilizing the vertical wire itself at the transmitting station as the oscillator, I propose to impress upon this vertical wire, oscillations from an oscillator, which oscillations shall be of a frequency corresponding to the fundamental of the wire. Similarly at the receiving station, I shall draw from the vertical wire, only that component of the complex wave which is of lowest frequency.

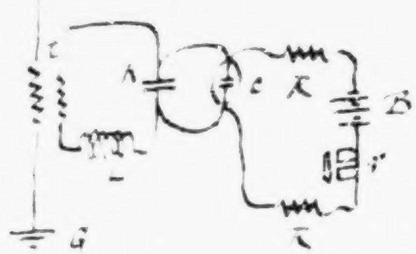
If now the fundamental of the wire at the receiving station be the same as that of wire at the transmitting station, then the receiving station may receive signals from the transmitting station, but if it be different from that of the transmitting station, it may not receive these signals.

By such an arrangement it is obvious we shall be enabled to have a large number of vertical wire stations at moderate

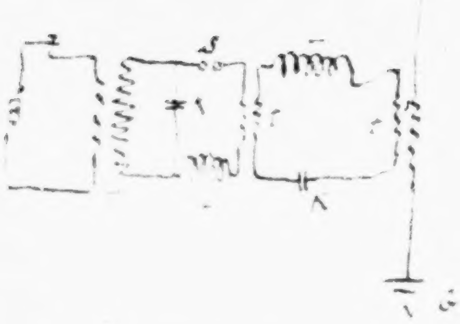
distances from each other each receiving station capable of only receiving the signals sent from from the transmitting station or stations from which it is adjusted to receive signals and the transmitting and receiving stations may not thus interfere with the operation of neighbouring stations. An arrangement of the apparatus is shown below.



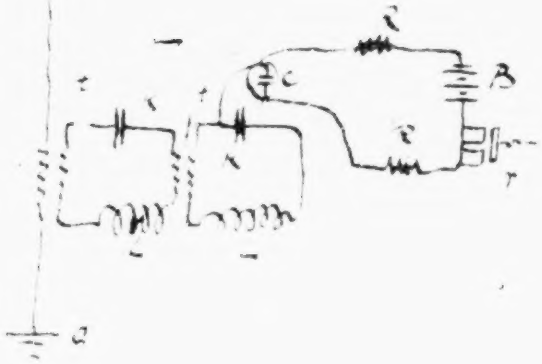
Transmitting Station



Receiving Station



Transmitting Station



Receiving Station

In these sketches, G is ground, K is condenser, C is coherer, L is inductance coil without iron, T is step-up transformer, t is transformer without iron, R is retardation coil, B is battery, r is relay.

The tuning of these circuits one to another and all to the same frequency will probably be best accomplished empirically, though the best general proportions may be determined mathematically.

Please let me know if the description I have given in this letter is sufficient to give you an intelligent understanding of the invention and ~~to enable you~~ in your belief to enable you to set up and operate the invention without more experimental work than that required to tune the circuits.

Cordially yours

John Stone Stone

G-3 3634

Subject: Space Telegraphy

July 18 1899

My dear Baker

As few save those who have made a special study of the subject are familiar with some of the theoretical considerations which are involved in space telegraphy by the so called Marconi or vertical wire system, I send you a brief description of the phenomena and of the theory.

In the usual arrangement, the connecting apparatus is that shown diagrammatically in Fig 1 below in which A is the transmitting station and A' is the receiving station.

a is a battery
b " key
c " condenser
p " circuit breaker
P " the primary of the spark coil I
S " secondary " " " I
s " a spark gap
[illegible] " vertical wire
g " ground connection
[illegible] coherer

I - inductance coil

R - relay or recorder

Fig. 2

When the key k is depressed, the spark coil I charges a high potential difference in its secondary which proceeds to charge the vertical wire to a high potential relative to the earth. This potential difference increases till it is sufficient to break down the air gap e whereupon the vertical wire discharges to earth through the spark gap the resistance of which is now insignificant relative to the impedance of the secondary S. The discharge of the vertical wire is oscillatory in character owing to the electro

static capacity and inductance or coefficient of self induction of the vertical wire, but owing to the fact that the electro-static capacity is distributed along the wire and is moreover not uniformly distributed (the different points along the wire being at different distances from the earth) the oscillations are not simple harmonic in character but may be represented by a Fourier's Series,

$A_1 \sin pt + A_2 \sin 2pt + A_3 \sin 3pt + \&c$

$+ B_0 + B_1 \cos pt + B_2 \cos 2pt + B_3 \cos 3pt + \&c.$

The oscillatory discharge of the vertical wire sets up corresponding electro-magnetic waves surrounding it, part of which are radiated with the velocity of light.

These electro magnetic radiations upon reaching the vertical wire at the receiving station set up corresponding electro-motive forces in it. You may, if you please, regard the electro-motive forces as due to the lines of magnetic force cutting the vertical wire at the receiving station.

The electro-motive forces so set up may obviously be represented by a corresponding

Fourier's series

$$A'_1 \sin pt + A'_2 \sin 2pt + A'_3 \sin 3pt + \&c$$

$$B_1 + B'_1 \cos pt + B'_2 \cos 2pt + B'_3 \cos 3pt + \&c.$$

The spark gap G at the receiving station being too great to be bridged by these slight electro-motive forces and the impedance of the coils R being very great to such high frequency electro-motive forces, they act in full force upon the coherer K which is normally of very high resistance but which, when acted upon by these rapidly varying electro-motive forces, is broken down or coheres and its resistance enormously diminishes.

The diminution in the resistance of the coherer permits a current from the battery E at the receiving station to pass through the coherer and this current operates the receiving instrument B.

Such in brief is the usual system.

In my arrangement the vibratory currents developed in the vertical wire is not due to the oscillatory discharge of the wire but is due to a simple harmonic electro-

motive force impressed upon it which electro-motive force produces forced current vibrations in the wire which forced vibrations as is well known depend for their period and form only upon the period and form of the impressed force and not upon the electro-magnetic constants of the circuit in which they are developed as is the case with free or natural vibrations of a system.
The current in the vertical wire in my system may therefore be represented by a simple harmonic

$$A_a \sin apt$$

and if the period of the impressed force be the same as that of the fundamental of the vertical wire, then it may be represented by

$$A_a \sin pt.$$

The radiations will also be simple harmonic and of the same periodicity p and will develop in the vertical wire at the receiving station, a corresponding simple harmonic electro-motive force

of periodicity p.
I place the coherer at the receiving station in a resonant circuit tuned to the periodicity p. Under these circumstances the coherer will be operated by the signals sent from the sending station described, but if a second sending station develops radiations of periodicity p_1 materially different from p then the receiving apparatus will not be affected by these radiations since the circuit in which the coherer is located is practically opaque to these radiations or more properly speaking to the currents which these radiations are capable of exciting.
The spark transmitting circuit shown in my letter to you of June 30th is practically the same as that employed by Tesla for the production of high frequency currents except that I place an inductance coil L in the circuit to give additional means of tuning and to cut off by its greater inductance the reaction from the induction

coil 2 which would tend to make the oscillations multiperiodic instead of simple harmonic. The inductance of this coil should be made large compared to the inductance of the primary. By the use of an auxiliary inductance coil for the purpose of rendering the oscillations simple harmonic in the case of circuits connected with other circuits as described [illegible] made of [illegible] I have elsewhere given a mathematical demonstration of the fact that in accomplishing this purpose.

The transformer T charges the condenser [illegible] to a point where the spark gap [illegible] breaks down. When this happens the condenser discharges through the spark gap, primary of T and auxiliary inductance coil [illegible] giving a practically simple harmonic current. A high frequency generator would be more preferable to this arrangement.

In the receiving station the coil [illegible] and condenser [illegible] form a resonant circuit which is attuned to the frequency of the

current developed at the transmitting station. Again the inductance of the coil L should be made large compared to the inductance of the secondary of the induction coil t at the receiving station in order to obtain well defined resonance to a single frequency.

I believe that I was the first to discover that it was desirable to place an auxiliary inductance coil of large inductance in a secondary circuit in order to make it resonant to a definite frequency. I have elsewhere shown that it accomplishes this purpose.

In the second case of transmitting and receiving stations shown in my letter to you of June 30 ultimo, everything is the same as that shown in the first two diagrams except that an additional resonant circuit attuned to the same frequency as the others, is interposed between the vertical wires and the transmitting and receiving apparatus for the purpose of additionally sifting out the undesired harmonics.

A modification of the oscillator circuit shown in my previous letter to you and a modification which I believe would be useful consist in interchanging the position of the condenser K and spark gap S in the transmitting circuit as shown in Fig 2 below.

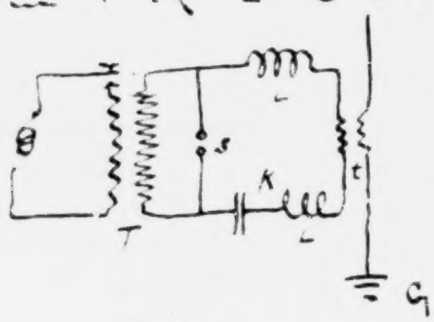


Fig 2.

A secondary circuit of comparatively low impedance may then be used in; the transformer T which has its advantages and there is less liability to the dri-ving circuit through the secondary of T producing a disturbance in the periodicity of the current developed in the resonant circuit S-L-K.

Cordially yours

John Stone Stone

[fol. 3207] Answer. I think so.

34. Dedirect question. Does that apply to any other part of this article?

Answer. I am afraid I do not understand your question.

35. Redirect question. Was any other part of this article as here copied written then for the first time?

Answer. The article in the book?

36. Redirect question. By "article" I mean these notes?

Answer. That is the only thing; yes, sir.

37. Redirect question. Do you now remember how you came to make this addition to the notes?

Answer. After having reread the article referred to in the lecture, I probably jotted that down to indicate the particular bearing on the subject in question.

DEFENDANT'S EXHIBIT E-3

(Defendant's Exhibit No. 1, Baker deposition)

Boston, July 22, 1899.

MR. JOHN STONE STONE,
Phillips Building, Boston, Mass.

MY DEAR STONE:

Your letters of July 18th and June 20th last were received in due course, and have been read with great interest. The "selective" methods of space telegraphy therein described I believe I understand sufficiently to set up and operate them.

Allow me to add that this speculation of the work which Marconi's experiments to date leave in rather primitive condition is very important and should be prosecuted without delay by way of further development and protection by letters patent.

Yours very cordially, Joseph B. Baker.

Defendant's Exhibit H-3

(Defendant's Exhibit No. 4, Baker deposition)

In The United States Patent Office. Serial No. 44384. Room No. 91. Application of John Stone Stone, for Apparatus for Selective Electric Signaling. Filed January 23, 1901

Affidavit of Joseph B. Baker

Joseph B. Baker, of lawful age, being duly sworn, deposes and says as follows:

I am well acquainted with Mr. John Stone Stone, the applicant in the above-entitled case, having been associated with him for several years at the laboratory of the American Bell Telephone Co. at Boston, where I was engaged in electrical experimentation for that company.

I am a graduate of the Massachusetts Institute of Technology with the degree of electrical engineer, and for some [fol. 3208] years acted as electrician for the American Telephone and Telegraph Company at Boston.

I have carefully examined a copy of the specification and drawings in the above-entitled case. Prior to November, 1899, Mr. Stone, the applicant, sent to me at Newton, Mass., by mail, a full and complete written description with drawings of the invention described and claimed in this case, which I duly received and read and fully understood. Also, prior to the time above named, I wrote and mailed to Mr. Stone a letter in which I stated that I had received his description and understood it and believed myself capable of putting the same in practice.

Joseph B. Baker.

Boston, Mass., March 18, 1901.

Subscribed and sworn to before me. Charles C. Kurtz, *Notary Public.*

DEFENDANT'S EXHIBIT 1-3

(Defendant's Exhibit No. 5, Baker deposition)

In the United States Patent Office. Room 109. Application of JOHN STONE STONE for patent for improvement in space telegraphy. Serial number 182544. (Case F.) Filed November 24, 1903

STATE OF MASSACHUSETTS,
County of Suffolk, ss:

JOSEPH E. BAKER, of lawful age, being first duly sworn, deposes and says, as follows:

I reside at Wellesley Hills, in the county of Norfolk and State of Massachusetts.

I am well acquainted with Mr. John Stone Stone, the applicant named in the above-entitled case, having been associated with him for several years at the laboratory of the American Bell Telephone Company at Boston, where I was engaged in electrical experimentation for that company.

I am a graduate of the Massachusetts Institute of Technology with the degree of electrical engineer and for some years acted as electrician for the American Telephone and Telegraph Company at Boston.

Prior to December 15, 1899, I received from Mr. Stone two letters containing a full and complete written description with drawings of a system of selective electric signaling by simple harmonic electromagnetic waves.

Also prior to December 15, 1899, I wrote and mailed to Mr. Stone a letter in which I stated that I had received his description and understood it and believed myself capable of putting the same in practice.

The photolithographic copies of the letters annexed hereto and marked "Exhibit A" and "Exhibit B" are facsimiles of the letters received by me from Mr. Stone as aforesaid. [fol. 3299] The photolithographic copy of the letter annexed hereto and marked "Exhibit C" is a facsimile of the letter sent by me to Mr. Stone in acknowledgment of his letters, as aforesaid.

I am the same Joseph B. Baker who executed an affidavit to substantially the same facts set forth above on March 18, 1901, which affidavit I am informed and believe now forms a

part of the record of patent No. 714831 in the archives of the United States Patent Office.

The letter referred to by me in said affidavit is the same letter referred to herein, a copy of which is hereunto annexed as "Exhibit A."

(Signed) Joseph B. Baker.

Sworn and subscribed before me this 29th day of January, 1904. (Signed) Benj. F. Haines, *Notary Public.*

DEFENDANT'S EXHIBIT K-3

(Defendant's Exhibit No. 7, Stone deposition)

Joseph B. Baker, consulting electrical engineer. Office and laboratory, 40 Lincoln St., Boston. Telephone 1293 Oxford.

Boston, June 3, 1902.

ALEXANDER P. BROWNE, ESQ.,
31 *State Street*, Boston, Mass.

MY DEAR BROWNE:

In accordance with your letter of May 28th, I have hunted up three letters written me by Stone in the summer of 1899. I hope one or more of these will be useful to you.

The letters herewith are of date June 23, 1899, June 30, 1899, and July 18, 1899.

Very truly yours, Joseph B. Baker.

DEFENDANT'S EXHIBIT N-3

(Defendant's Exhibit No. 10, Stone deposition)

Boston, July 22, 1899.

MR. JOHN STONE STONE:
Phillips Building, Boston, Mass.

MY DEAR STONE: Your letters of July 18th and June 20 last were received in due course and have been read with great interest. The "selective" methods of space telegraphy

therein described I believe I understand sufficiently to set up and operate them.

Allow me to add that this specialization of the work, which Marconi's experiments to date leave in rather primitive condition, is very important, and should be prosecuted without delay by way of further development, and protection by letters.

Yours very cordially, Joseph B. Baker.

[fol. 3210] As it was necessary to send the original to Heliotype Printing Co., 211 Tremont St., on January 4th, 1904, the above copy was made by me on that date, and I hereby state it to be a true copy of the original document.

G. A. Higgins. (Seal.)

Then personally appeared before me the said G. A. Higgins and made oath that the foregoing statements by her are true.

George Lemist Clarke, *Notary Public.* (Seal.)

I hereby certify that I have compared the original letter from Joseph B. Baker to Mr. John Stone Stone, dated Boston, July 22d, 1899, with the above copy and find the above to be a true copy of the original letter before mentioned.

George Lemist Clarke, *Notary Public.*

UNITED STATES PATENT OFFICE.

JOHN STONE STONE, OF BOSTON, MASSACHUSETTS, ASSIGNOR TO LOUIS E. WHICHER, ALEXANDER P. BROWNE, AND BRAINERD T. JUDKINS, TRUSTEES.

METHOD OF SELECTIVE ELECTRIC SIGNALING.

SPECIFICATION forming part of Letters Patent No. 714,756, dated December 2, 1902.

Application filed February 8, 1900. Serial No. 4,505. (No model.)

To all whom it may concern:

Be it known that I, JOHN STONE STONE, a citizen of the United States, residing at Boston, in the county of Suffolk and State of Massachusetts, have invented certain new and useful Improvements in Methods of Selective Electric Signaling, of which the following is a specification.

My invention relates to the art of transmitting intelligence from one station to another by means of electromagnetic waves without the use of wires to guide the waves to their destination; and it relates more particularly to the system of such transmission in which the electromagnetic waves are developed by producing electric vibrations in an elevated conductor preferably vertically elevated.

Heretofore in signaling between two stations by means of electromagnetic waves when the stations are not connected by a conducting-wire certain disadvantageous limitations have been observed which greatly militated against the commercial value of the methods employed. When the electromagnetic waves are developed by producing natural or forced electric vibrations in a horizontal conductor, the attenuation of the waves so developed as they travel away from the conductor is found to be so great as to very seriously limit the distance to which they may be transmitted and effectively received, the chief cause of this observed phenomenon probably being that owing to the horizontal position of the conductor the plane of polarization of the waves is such as to cause the rapid absorption of the energy of the waves by the conducting-surface of the earth or water over which they travel. This difficulty has been overcome by a method of developing the waves which consists in producing natural electric vibrations in a vertically elevated conductor, in which case the plane of polarization of the wave so produced is at quadrature with that of the waves which may be developed by a horizontal wire and in case of the vertical conductor the attenuation of the waves is observed to be very much less than in the case of the horizontal conductor, so that these waves may be transmitted to and effectively received at much greater distances. A limitation of the commercial utility of this system is, however, observed, which depends upon the fact that it has not heretofore been found possible, so far as I am aware, to direct signals sent out from a transmitter-station to the particular receiving-station with which it is desired to communicate to the exclusion of other receiving-stations equipped with equally or more sensitive receiving apparatus and located within the radius of influence of the sending-station. Electromagnetic waves have also been developed by producing natural or forced electric oscillations in loops or coils of wire at the transmitting-station and also by means of the discharge of electricity between two conducting spheres, cylinders, or cones; but in such cases the sphere of influence is so limited as to greatly restrict the commercial utility of these two methods of developing the signal-waves. In fine, the method of signaling by means of electromagnetic waves between stations not connected by a conducting-wire, in which method the electromagnetic waves are developed by electric vibrations in an elevated conductor, has great advantages over the other existing or proposed methods for accomplishing this purpose in which the electromagnetic waves are developed by other means, since in the case of the waves developed by the elevated-conductor method the waves may be transmitted to and effectively received at greater distances than by the other systems; but whereas in the systems employing the other methods of generating the waves the signals developed may, at least theoretically, be directed to the particular receiving-station with which it is desired to communicate to the exclusion of other similar receiving-stations in the neighborhood. It has heretofore been found impossible, so far as I know, to accomplish this purpose in the system employing an elevated conductor or wire as the source of the electromagnetic waves.

The object of this invention is to overcome the hereinbefore-described limitation to the system in which the waves emanate from vertical conductors, so that in such systems the transmitting-stations may selectively trans-

mit their signals each to a particular receiving-station simultaneously or otherwise without mutual interference.

It is also the object of the invention to provide means whereby each of a plurality of transmitting and receiving stations in such a system may be enabled to selectively place itself in communication with any other station to the exclusion of all the remaining stations.

It is further the object of the present invention to enable the vertical or elevated conductor in such a system to be made the source of simple harmonic electromagnetic waves of any desired frequency independent of its length and other geometrical constants. Thus the frequency impressed upon the elevated conductor may or may not be the same as the natural period or fundamental of such conductor; but, as will be hereinafter explained, an elevated conductor that is aperiodic may be employed and is best adapted for use when the apparatus is to be used successively for different frequencies, and such aperiodic elevated conductor is likewise the preferred form of elevated conductor when two or more frequencies are to be simultaneously impressed upon or received by a single elevated conductor; but forced simple harmonic electric vibrations of different periodicities may each be separately impressed upon a different elevated conductor, and the several energies of the resulting electromagnetic waves may be selectively conveyed each to a separate translating device.

Before proceeding to describe the invention certain fundamental principles relative to electrical vibrations should be stated, as these principles are involved in the art of signaling by means of what may be called "unguided electromagnetic waves."

If the electrical equilibrium of a conductor be abruptly disturbed and the conductor thereafter be left to itself, electric currents will flow in the conductor, which tend to ultimately restore the condition of electrical equilibrium. These currents may be either unidirectional or oscillatory in character, depending upon the relation between the principal electromagnetic constants of the conductor—*i. e.*, upon its electromagnetic and electrostatic capacities and its resistance. These phenomena are analogous to the mechanical phenomena which are observed when the mechanical equilibrium of a system is abruptly disturbed and the system is thereafter left to itself. In the case of a mechanical system motions result which tend to restore the mechanical equilibrium of the system. These motions may consist either of a unidirectional displacement or of to-and-fro vibrations of the system or parts of the system, depending upon the relations which subsist between the principal mechanical constants of the system—*i. e.*, its moments of mass and elasticity and its friction coefficients. In general the determination of the relations which must subsist in order that an oscillatory restoration of equilibrium shall take place, either in an electric or in a mechanical system, and the determination of the period of these oscillations is very difficult; but in certain simple cases both the determination of the conditions for an oscillatory restoration of equilibrium and of the period of these oscillations is quite simple.

An example of a simple mechanical system capable of an oscillatory restoration of equilibrium is to be found in the torsional pendulum, which consists of a highly elastic wire fixed at one end and supporting at its other extremity a heavy mass called the "bob." If a torsional stress be imparted to the wire of this pendulum by turning the bob about the axis of the wire and the bob be then abruptly released, the pendulum will in general execute isochronous oscillations about the axis of the suspending-wire in the process of restoration of equilibrium. An example of a simple electrical system capable of an oscillatory restoration of equilibrium is to be found in the case of a circuit consisting simply of a condenser and a coil without iron in its core, as shown in Figure 1 of the accompanying drawings, in which C is a condenser and I is a coil without iron in its core. If a charge of electricity be imparted to the condenser and if its electrodes be then connected to the coil, as shown in Fig. 1, an isochronous oscillatory current will in general be developed in the circuit in the process of restoration of its electrical equilibrium. Such a simple circuit as that shown in Fig. 1 is known as a system with a single degree of freedom, and the electric oscillations which it supports when its equilibrium is abruptly disturbed and it is then left to itself are known as the natural vibrations or oscillations of the system. These vibrations begin with a maximum of amplitude and gradually die away in accordance with what is known as an "exponential" law and are what are known as "simple harmonic vibrations." They may be represented graphically as in Fig. 2, in which A is a curve drawn to rectangular coördinates, in which the ordinates represent instantaneous values of current strength and the abscissæ represent times. When two such simple circuits are associated together inductively, as shown in Fig. 3, the system so formed is known as a system of two degrees of freedom, and in the oscillatory restorations of equilibrium—*i. e.*, in the natural vibrations in such circuits—the currents are in general not simple harmonic in character, but in general consist of the superposition of two simple harmonic currents, as shown in Fig. 4. In general, if n simple circuits, such as shown in Fig. 1, be associated together in a system either by conductive or by inductive connections a system of at least n degrees of freedom results, and the natural vibrations of such a system will therefore consist of the superposition of at least n currents. It is, moreover, a fact that the diffi-

ent simple harmonic components of the oscillations which together constitute the oscillatory restoration of equilibrium of a complex system are in general not the same as those of the separate simple circuits when these circuits are isolated from one another; but the presence of each simple circuit modifies the natural period of each of the other circuits with which it is associated. Thus in a particular case if there be two simple circuits, the first with a natural period of .004 of a second when isolated, and the second with a period of .0025 of a second when isolated; these circuits when inductively connected, as shown in Fig. 3, may have an oscillatory restoration of equilibrium of which the simple harmonic components are .00444 of a second, and .00159 of a second, showing that the inductive association of the circuits together has increased the natural period of the high-period circuit, and decreased the natural period of the low-period circuit. It is, moreover, to be remembered that during the restoration of electric equilibrium currents of each of the periods are found in each of the circuits of the connected system.

So far we have considered the natural vibrations of electric systems—*i. e.*, the electric vibrations, by means of which the electric equilibrium of circuits is restored after it has been abruptly destroyed and the circuits are left to themselves—and we have compared the simple case of such natural electric vibrations with the corresponding natural mechanical vibrations of mechanical systems. We have seen that simple circuits may have simple harmonic natural electric oscillations and that complex circuits will in general have complex electric oscillations. We have, moreover, seen that the natural period of oscillations depended upon the electromagnetic constants of the circuit in the case of a simple circuit and that each of the periods of oscillation in the case of a complex or of interrelated circuits depended upon the electromagnetic constants of each of the interrelated circuits; but, besides the ability to execute natural vibrations or oscillations both electric and mechanical systems are capable of supporting what are termed "forced vibrations," and in the case of forced vibrations the period of the vibration is independent of the electromagnetic constants of the circuit, on the one hand, and the mechanical constants of the mechanical system, on the other hand, and depends only upon the period of the impressed force. Thus if a simple harmonic electromotive force be impressed upon a circuit free from hysteresis, whether it be a simple circuit or a complex of simple circuits, the forced vibrations or currents resulting from this impressed force will also be simple harmonic and of the same period as that of the impressed force.

In the present system of signaling by means of electromagnetic waves, in which a vertical conductor is employed as the source of electromagnetic radiations, the electric oscillations are of the kind hereinbefore described as natural vibrations, the vertical conductor being charged to a high potential relative to the surrounding earth and permitted to abruptly discharge to earth by means of an electric spark between two ball-electrodes. In such a method of developing the electromagnetic waves the oscillations are necessarily of a complex character, and therefore the resulting electromagnetic waves are of a complex character and consist of a great variety of superimposed simple harmonic vibrations of different frequencies. The vibrations consist of a simple harmonic vibration of lower period than all the others, known as the "fundamental," with a great variety of simple harmonics of higher periodicity superimposed thereon. Similarly the vertical conductor at the receiving-station is capable of receiving and responding to vibrations of a great variety of frequencies, so that the electromagnetic waves which emanate from one vertical conductor used as a transmitter are capable of exciting vibrations in any other vertical wire as a receiver, and for this reason any transmitting-station in a system of this character will operate any receiving-station within its sphere of influence, and the messages from the transmitting-station will not be selectively received by the particular receiving-station with which it is desired to communicate, but will interfere with the operation of other receiving-stations within its sphere of influence, thereby preventing them from properly responding to the signals of the transmitting-stations from which they are intended to receive their signals.

By my invention the vertical conductor of the transmitting-station is made the source of electromagnetic waves of but a single periodicity, and the translating apparatus at the receiving-station is caused to be selectively responsive to waves of but a single periodicity, so that the transmitting apparatus corresponds to a tuning-fork sending but a single simple musical tone, and the receiving apparatus corresponds to an acoustic resonator capable of absorbing the energy of that single simple musical tone only. When, however, the elevated conductor is aperiodic, it is adapted to receive or transmit all frequencies, and accordingly a single aperiodic elevated conductor may be associated with a plurality of local circuits, each attuned to a different frequency after the manner now well known in the art of multiple telegraphy by wire conductors.

When a single elevated conductor is to be made a source of a plurality of signal-waves of different frequences and when, moreover, these signal-waves are to be simultaneously developed, it is obviously necessary that the trains of waves of different frequencies developed at the elevated conductor shall be

independent of each other—*i. e.*, it is necessary that the electric vibrations of one frequency impressed upon the elevated conductor shall not be affected by the act of simultaneously impressing vibrations of another frequency upon the conductor. The manner of developing the individual electric vibrations of a particular frequency described in this specification is such as to insure *per se* the required independence of the vibrations when several different frequencies are simultaneously impressed upon the elevated conductor. Several forms of such arrangements of the apparatus will, nevertheless, be herein after fully described in order to add to the completeness of the specification.

When the apparatus at a particular station is attuned to the same periodicity as that of the electromagnetic waves emanating from a particular transmitting-station, then this receiving-station will respond to and be capable of selectively receiving messages from that particular transmitting-station to the exclusion of messages simultaneously or otherwise sent from other transmitting-stations in the neighborhood which generate electromagnetic waves of different periodicities. Moreover, by my invention the operator at the transmitting or receiving station may at will adjust the apparatus at his command in such a way as to place himself in communication with any one of a number of stations in the neighborhood by bringing his apparatus into resonance with the periodicity employed by the station with which inter-communication is desired.

In order that the vertical conductor at the transmitting-station shall generate harmonic electromagnetic waves of but a single frequency, I cause the electric vibrations in the conductor to be of a simple harmonic character, and this in turn I accomplish by producing what are substantially forced electric vibrations in the vertical conductor in lieu of producing natural vibrations in the conductor, as has heretofore been practiced. In order that the electric translating apparatus at the receiving-station shall be operated only by electric waves of a single frequency and by no others, I interpose between the vertical conductor at the receiving-station and the translating devices a resonant circuit or circuits attuned to the particular frequency of the electromagnetic waves which it is desired to have operate the translating devices.

Having thus described, broadly, the nature and object of the invention and the electrical principles upon which it is based, the details of the invention may best be described by reference to the drawings which accompany and form a part of this specification. Like letters, so far as may be, represent similar parts in all the figures.

Figs. 1 to 4 are diagrams already referred to. Fig. 5 is a diagram illustrating one arrangement of the transmitting-station. Fig. 6 is a diagram illustrating an arrangement of the receiving-station. Fig. 7 is a diagram illustrating another form of the transmitting-station. Fig. 8 is a diagram illustrating another form of the receiving-station. Figs. [illegible] and 15 are diagrams illustrating a detail of the construction at both transmitting and receiving stations. Figs. 10 and 11 are diagrams illustrative of the connection of the coherer at receiving-stations. Fig. 12 is a diagram illustrating the connection of a condenser-telephone at the receiving-station. Figs. 13 and 16 are diagrams illustrative of forms of transmitter-stations capable of developing signal-waves of two different frequencies. Figs. 14 and 17 are diagrams illustrative of forms of receiving-stations capable of receiving selectively signal-waves of [illegible] different frequencies.

In the drawings, [illegible] represents a vertical or virtually vertical conductor grounded in the earth connection E.

M, M′, M″, and M‴ are induction-coils whose primary and secondary wires are I, I_1, I', I_1', and I'', I_1'' and I_2, I_3, I_2', I_3', respectively.

L, L', and L'' are auxiliary inductance-coils.

C, C′, C″, and C‴ are electrical condensers.

K and K_1 are coherers.

B is an electric battery.

a is an alternating-current generator.

k and k_1 are circuit-closing keys.

R and R_1 are telegraphic relays or other suitable electric translating devices.

p and p_1 are automatic circuit-interrupters.

s and s_1 are spark-gaps.

In the organization illustrated in Fig. 5 the generator *a* develops an alternating electromotive force of moderate frequency, which when the key *k* is depressed develops a current in the primary circuit of the transformer M′. The transformer M′ is so designed as to transform the electromotive force in the primary circuit to a very high electromotive force in the secondary. As the potential difference at the terminals of the secondary rises, the charge in the condenser [illegible] till the potential difference is sufficient to break down the dielectric at the spark-gap. When this occurs, the condenser [illegible] discharges through the spark-gap *s*, the primary I, and the inductance-coil L. This discharge is oscillatory in character and of very high frequency, as will be explained hereinafter. The high-frequency current so developed [illegible] through the primary I, induces a corresponding high-frequency electromotive force and current in the secondary I_1, and [illegible] electric vibrations result in the vertical conductor [illegible], which are practically of a simple harmonic character. These simple harmonic vibrations in the conductor [illegible] develop electromagnetic waves, which are also [illegible] simple harmonic in character, and these in turn on impinging upon the vertical conductor at the receiving-station develop [illegible]

corresponding simple harmonic vibrations of like frequency.

In the organization illustrated in Fig. 6 the simple harmonic electromagnetic waves of a given frequency or periodicity impinging upon the vertical conductor v develop therein corresponding electrical vibrations of like frequency. By means of the induction-coil M a vibratory electromotive force corresponding in frequency to the electric vibrations in the conductor v is induced in the secondary circuit I_1 L C C′. If the frequency of this induced electromotive force is that to which the circuit I_1 L C C′ is attuned, there will be a maximum potential difference developed at the plates of the condenser C, and this potential will operate the coherer K. When the coherer K operates, the resistance of the circuit B R K is enormously diminished and the battery B develops a current which operates the translating device R. The decoherer (not shown in the drawing) is thereby set in operation and as soon as the impulse passes the coherer is restored to its sensitive condition. If, however, the frequency of the electromagnetic waves which impinge upon the vertical conductor v of the receiving-station depicted in Fig. 6 is not the same as that to which the circuit I_1 L C C′ is attuned, the electromotive force induced in this circuit will be different from that to which the circuit will respond by virtue of resonance and there will be but a negligible potential difference developed at the plates of the condenser C. Under these circumstances the coherer K will not be operated and the signals will not actuate the translating device R.

When transmitting-stations and a corresponding number of receiving-stations are employed by adjusting the electromagnetic constants of the circuits at the various receiving-stations, these circuits may be so proportioned or tuned that the energy of the electromagnetic waves emanating from any given transmitting-station will be selectively received and absorbed at a given receiving-station.

Before proceeding to a description of the operation of the other two forms of transmitting and receiving stations shown in Figs. 7 and 8 it is to be noted that the condenser C in Fig. 5 discharges through the circuit s I_1 L, and its discharge is practically unaffected by its conductive connection with the circuit through I'_2. The reason for this is that the impedance offered by the circuit through I'_2 is enormously greater than that through s I_1 L. Also the discharge through the circuit s I_1 L is of very great frequency, because the frequency of the oscillations of such discharges of condensers is approximately inversely proportional to the square root of the product of the inductance of the circuit by the capacity of the condenser, and for the purpose of this invention the apparatus is so designed that the product of the capacity of the condenser by the inductance of the circuit is made numerically very small. Moreover, the oscillations in the circuit s I_1 L are approximately simple harmonic in character and are practically unaffected by the inductive association with the vertical wire, because of the auxiliary inductance furnished by the coil L, it being capable of demonstration that if by means of the coil L the inductance of the circuit L I_1 s is rendered large compared to the mutual inductance between this circuit and the vertical wire the natural oscillations which will take place in the circuit s I_1 L will be practically unaffected by the inductive association with the vertical wire and will therefore be practically of a simple harmonic character, as in the case of the isolated simple circuit shown in Fig. 1. The principle may for the present purpose be stated thus—that when two simple oscillators, each such as that shown in Fig. 1, are inductively associated with each other, as in Fig. 3, the system is a system of two degrees of freedom, and the natural period of oscillation of each simple circuit is modified by the presence of the other; but if the proportions of the circuits be such that the product of the inductances of the two circuits is large compared to the mutual inductance between the circuits the natural period of oscillation of each of the circuits becomes practically the same as if the circuits were isolated.

The mathematical expression for the frequency to which a circuit is resonant when it is isolated from all other circuits—*i. e.*, has but a single degree of freedom—is well known and may be stated as follows:

$$n = \frac{1}{2\pi\sqrt{C_1 L_1}}$$

from which

$$L_1 = \frac{1}{C_1 p^2},$$

where n is the frequency, C_1 is the capacity, L_1 is the inductance, and p is the periodicity, which equals $2\pi n$. In the case of a circuit of two degrees of freedom, however, in order to make the component circuits each responsive to the same frequency as when isolated—in other words, to overcome the modifying effect of the mutual inductance of each circuit upon the other—it is necessary to consider, in the case of inductive relation, the expression:

$$\frac{1}{C_1 p^2} = L_1 - \frac{M^2_{12}\, p \left(L_2 p - \frac{1}{C_2 p}\right)}{R^2_2 + \left(L_2 p - \frac{1}{C_2 p}\right)^2},$$

where C_1 L_1 are the capacity and inductance of the first circuit, C_2 L_2 R_2 are the capacity, inductance, and resistance, respectively, of the second circuit, and M_{12} is the mutual inductance of the circuits. From these expressions careful consideration will show that the ef-

fective inductance of the first circuit has been modified by its inductive relation with the second circuit, and it is:

$$L'_1 = L_1 - \frac{M^2_{12}\, p \left(L_2 p - \frac{1}{C_2 p}\right)}{R^2_2 + \left(L_2 p - \frac{1}{C_2 p}\right)^2}$$

Similarly we have to consider the expression

$$\frac{1}{C_2 p^2} = L_2 - \frac{M^2_{12}\, p \left(L_1 p - \frac{1}{C_1 p}\right)}{R^2_1 + \left(L_1 p - \frac{1}{C_1 p}\right)^2}$$

from which it will be seen that the effective inductance of the second circuit has been modified by its inductive relation with the first circuit and is:

$$L'_2 = L_2 - \frac{M^2_{12}\, p \left(L_1 p - \frac{1}{C_1 p}\right)}{R^2_1 + \left(L_1 p - \frac{1}{C_1 p}\right)^2}$$

These two inductances L'_1 and L'_2 are the apparent inductances which each of these circuits would have if acting as the primary to induce simple harmonic vibrations of frequency s in the other. It is therefore necessary in order to overcome the modifying effect of the mutual inductance on either circuit to add to that circuit an auxiliary inductance-coil of inductance large compared to the term of the form:

$$\frac{M^2 p \left(L p - \frac{1}{C p}\right)}{R^2 + \left(L p - \frac{1}{C p}\right)^2},$$

or at least so large that when it is added to the natural inductance of the circuit the sum of their inductances is very large compared to the said term. If, further, the electric equilibrium of the circuit s I_1 L be abruptly disturbed and the circuit be then left without impressed force, the oscillations which are developed in it induce corresponding oscillations in the vertical wire, which oscillations are virtually forced vibrations, corresponding in frequency with the natural oscillations developed in the circuit s I_1 L and being practically independent, as regards their frequency, of the constants of the second circuit in which they are induced.

It is to be understood that any suitable device may be employed to develop the simple harmonic force impressed upon the vertical wire. It is sufficient to develop in the vertical wire practically simple harmonic vibrations of a fixed and high frequency.

The vertical wire may with advantage be so constructed as to be highly resonant to a particular frequency, and the harmonic vibrations impressed thereon may with advantage be of that frequency. The construction of such a vertical wire is shown and described in other applications of mine now pending.

At the receiving-station shown in Fig. 6 the inductance-coil L is introduced in order to supply auxiliary inductance and to permit of the circuit C' C' I L being attuned to a particular frequency practically independently of the constants of the vertical wire.

In both the organizations illustrated in Figs. 5 and 6 the inductance-coils L may be made adjustable and serve as a means whereby the operators may adjust the apparatus to the particular frequency which it is intended to employ.

Passing now to the organizations illustrated in Figs. 7 and 8, it is to be noted that they differ, respectively, from those illustrated in Figs. 5 and 6 in that additional resonant circuits C I'_2 L I_1 are interposed between the vertical conductor and the generating and translating devices, respectively.

In the transmitter arrangements illustrated in Fig. 7 the circuit C I'_2 L I_1 is attuned to the same period as the circuit C' L I_1 s and merely tends to weed out and thereby screen the vertical wire from any harmonics which may exist in the current developed in the circuit C' L I_1 s. This screening action of an interposed resonant circuit is due to the well-known property of such circuits by which a resonant circuit favors the development in it of simple harmonic currents of the period to which it is attuned and strongly opposes the development in it of simple harmonic currents of other periodicities. In this organization an ordinary spark-coil, (shown at M'',) equipped in the usual way with an interrupter p and condenser C'', is employed, the current being supplied by the battery B. The operation of this organization is substantially the same as that of the organization shown in Fig. 5, hereinbefore described, except for the screening action of the circuit C I'_2 L I_1 and need not therefore be further described. Suffice it to say that when the source of vibratory currents is particularly rich in harmonics any suitable number of resonant circuits, each attuned to the desired frequency, may be connected inductively in series, as shown in Figs. 9 and 15, and interposed between the generating device and the vertical conductor for the purpose of screening the vertical conductor from the undesirable harmonics.

In the organization illustrated in Fig. 8 the electric resonator C I_2 L I_1, interposed between the vertical conductor and the circuit containing the coherer, is attuned to the same period as the circuit I C' C' I_1 and acts to screen the coherer-circuit from the effect of all currents developed in the vertical conductor, save that of the current of the particular period to which the receiving-station is intended to respond. As in the case of the transmitting-station, any suitable number of resonant circuits, each attuned to the particular period to which the station is desired to respond, may be

connected, as shown in Figs. 9 and 15, and interposed between the vertical conductor and the coherer-circuit. Such circuits so interposed serve to screen the receiver from the effect of all currents which may be induced in the vertical conductor that are not of the period to which the receiving-station is intended to respond.

The apparatus shown in Figs. 13, 14, 15, 16, and 17 illustrate methods of associating the apparatus hereinbefore described, and illustrated in Figs. 5, 6, 7, 8, and 9, when two or more stations are to be associated with a common elevated conductor. The operation of each individual station is the same as that already described in connection with Figs. 5, 6, 7, 8, and 9. For the sake of clearness only two stations are shown associated with the common elevated conductor V in the drawings; but it is obvious that any desired number of stations may be associated with a common elevated conductor in the same manner.

An inspection of the drawings will show that Figs. 13 and 16 illustrate two transmitting-stations of the type shown in Fig. 7 associated with a common elevated conductor, whereas Figs. 14 and 17 illustrate two receiving-stations of the type shown in Fig. 8 associated with a common elevated conductor.

When a plurality of stations are associated with a common elevated conductor, each of the stations is characterized by being tuned to a different frequency from that of any of the other stations so associated.

In Figs. 13, 14, 15, 16, and 17 it will be observed that the two different stations associated with a common elevated conductor have therein been differentiated by attaching a subscript to the letters of reference in the case of one of the stations and not to the letters of reference of the other station.

The operation of each of the transmitting-stations in Figs. 13 and 16 is identical with that of the transmitting-station illustrated in Fig. 7, and the operation of each of the receiving-stations shown in Figs. 14 and 17 is identical with the operation of the receiving-station illustrated in Fig. 8.

To illustrate, the step-up transformer or spark-coil M'' in Figs. 13 and 16 is equipped with an interrupter p and condenser C''', and the current is supplied by the battery B. When the key k is depressed, a high potential is developed in the secondary of M''. As the potential difference at the terminals of the secondary of M'' rises, the condenser C'' is charged till the resulting potential difference at s is sufficient to break down the spark-gap s. When this occurs, the condenser C'' discharges through the spark-gap s, the primary of M', and the inductance-coil L'. This circuit is attuned to a given high frequency, and the oscillatory current which results is therefore of that frequency. This current induces a similar current in the interposed resonant circuit L M C' M, attuned to the same frequency, which current in turn induces a current of corresponding frequency in the conductor V M E.

Passing now to the operation of the receiving-stations shown in Figs. 14 and 17 it may be remarked that since the operation of each of these stations is identical with the operation of the receiving-station shown in Fig. 8, the energy of the waves of one particular frequency will be absorbed by one of the receiving-stations and the energy of the waves of another particular frequency will be absorbed by the other receiving-station. This selective reception of the energy of waves of a particular frequency is independent of the number of waves of different frequencies which may be simultaneously present.

It is to be here noted that the above-described methods of simultaneously transmitting and receiving space-telegraph messages by a common elevated conductor are not described as the preferred methods, since the branch circuits M M_1 in Figs. 16 and 17 are not in themselves selective and since the elevated conductors in Figs. 13 and 14 contain a number of induction-coils in series not essential to the operation of any one of the stations singly, but that any way of associating a plurality of the stations shown in Figs. 5, 6, 7, and 8 with a vertical conductor will result in a system for simultaneously transmitting and receiving space-telegraph signals, owing to the fact that these stations are in themselves innerently selective and are capable of causing the independent development of vibrations of different frequencies in the elevated conductor and of selectively absorbing the energy of waves of different freqnencies.

The branch circuits M M_1 of Fig. 17 are not selective, since they contain but one element of a tuned circuit—viz., the inductance of M and M_1. Vibratory currents of whatever frequency they may be communicated by the vertical wire to these circuits will divide among them in simple inverse proportion to their electromagnetic impedances and are not selective except for a slight reaction due to the associated circuits C' M' L' and C'_1 M_1 L'_1. These reactions, so far from tending to make the branches selective to the frequencies to which their associated circuits are intended to respond, will, in fact, cause them to oppose more strongly currents of these frequencies than those to which the associated circuits are not attuned. Again, it is obvious that the inductance of the coil M in Fig. 13 is merely an additional impedance in the elevated conductor, which, to say the least, cannot assist in the development of vibrations in the elevated conductor impressed by circuit C'_1 M'_1 L'_1 M_1. The same is obviously true of the coil M_1 in the elevated conductor with reference to the operation of the circuit C' M' L'. Now passing to the transmitting station shown at Fig. 16 it is obvious that the vibrations communicated by the circuit C' M' L' to the elevated conductor V are sub-

ject to a shunt due to the coil M_1 in the other branch of the elevated conductor, and conversely the vibrations developed in the elevated conductor by the associated circuit $C_1 M'_1 L'_1$ are subject to a shunt due to the coil M in the other branch of the elevated conductor. Finally, the coil M in the elevated conductor in Fig. 14 can at best only present an impedance to the waves intended to be received by the circuit $C'_1 M'_1 L_1'$, and conversely the coil M_1 in the elevated conductor can at at best only present an impedance to the vibrations intended to be received by the circuit C' M' L'.

No mention has heretofore been made of the function of the condensers shown at C' in Fig. 6 and at C'' in Fig. 8, as those condensers are not essential to the tuning of the circuits in which they are placed, but merely serve to exclude the current of the batteries B from the resonant circuits. In order that these condensers may not appreciably affect the tuning of the circuits in which they are included, and thereby lower the resonant rise of potential at the plates of the condensers C and C', (shown in Figs. 6 and 8,) they are so constructed as to have large capacities compared to the capacities of C and C' in Figs. 6 and 8, respectively.

In Figs. 6 and 8 the coherers K are shown connected in shunt-circuit to the condensers C and C', respectively; but they may be connected serially in the resonant circuit, as shown in Fig. 10, or they may be connected in shunt-circuit to the coil L and condenser C, as shown in Fig. 11.

Though a coherer has been shown and described in the specification as the means of detecting the presence of oscillations in the receiving resonant circuits, under which circumstances it operates as a telegraphic relay to control a local-battery circuit including an electric translating device, any other suitable electroreceptive device may be employed to receive the signal—as, for example, a condenser-telephone. When a condenser-telephone is employed as a receiver, the receiving resonant circuit may be that illustrated in Fig. 12, in which C is the condenser-telephone and also the capacity by which the circuit L C C' L_1 is attuned.

In constructing the various parts of the apparatus shown and described in this specification there is great latitude as to the special forms that may be given them; but it must be remembered that when a circuit is to be tuned and it is desired to gain a high degree of resonance both electrostatic and magnetic hysteresis must be carefully excluded from the resonant circuit. For this reason all iron should be excluded from the coils in the resonant circuits and solid dielectrics should not ordinarily be employed in the condensers. These injunctions apply to the construction of resonant circuits attuned to very high frequencies, but not with the same force to the construction of resonant circuits to be tuned to low frequencies. Another precaution to be taken in the construction of the apparatus included in the resonants circuits when very high frequency currents are employed is that conductors between which there exists a considerable potential difference during the operation of the apparatus shall be kept as far apart as practical, because of the excessive displacement currents which tend to flow in the case of high-frequency currents. For this reason it will often be found to be convenient to build the coils in the form of flat spirals instead of long spirals of several layers, as is the usual construction of coils. Flat spirals with the turns well separated in order to minimize the displacement-currents between the turns are, however, by no means the only form of coils adapted to be used in conjunction with air-condensers for the purpose of tuning circuits to high frequencies and may often be neither the best nor most convenient form of coil to employ. Therefore in defining the character of the coils to be employed for this purpose it will be of advantage to first give the general theoretical considerations which lead to a special construction of the coils and to then give a practical guide to the manner of designing the coils for a particular frequency or range of frequencies.

A coil or solenoid as usually constructed consists of many turns of cotton or silk insulated wire wound on an insulating-core, such as a glass or ebonite tube or a wooden spool, the consecutive turns being separated only by the thin insulating coating of the wire. These solenoids, moreover, are in general wound with several layers of wire, the layers also being separated from each other only by the insulating coatings of the wires. Such solenoids are well adapted to be used in conjunction with condensers having solid dielectrics for the purpose of tuning circuits to low frequencies; but neither such coils nor such condensers are available for the purpose of tuning circuits to such high frequencies as are concerned in the present invention. In the case of high frequencies the energy absorbed in the solid dielectric of the condenser, due to dielectric hysteresis, is excessive, and the displacement-currents between the adjacent turns and layers of the coil mask and neutralize the inductance of the coil. Moreover, the solid dielectric forming the core of such coils exerts a deleterious effect, which in some instances is probably partially due to its possessing a small degree of conductivity, but which must in most instances be ascribed to the high specific inductive capacity of the material and to its dielectric hysteresis.

In order to tune a circuit to a predetermined high frequency, so that it shall show a well-defined selectivity for that frequency to the exclusion of other frequencies, even to the exclusion of frequencies differing but slightly from the predetermined frequency, it is necessary not only that the condenser

shall be free from dielectric hysteresis, but that the coil shall be so constructed as to behave for that frequency practically like a conductor having a fixed resistance and a fixed inductance, but devoid of capacity. Coils constructed in the usual way do not behave for high frequences as if they had a fixed resistance and inductance and no capacity, but partake more of the character of conductors having distributed resistance, inductance, and capacity. In fact, they may in some instances behave with high frequencies more like condensers than like conductors having fixed resistance and inductance and no capacity. Since a coil constructed in the usual way behaves for high frequencies as a conductor having distributed resistance, inductance, and capacity, it follows that such a coil will show for high frequencies the same quasi resonance as is observed with low frequencies in long aerial lines and cables—*i. e.*, that it will *per se* and without the intermediary of a condenser show a slight degree of selectivity for some particular frequency and for certain multiples of that frequency just as a stretched string which has distributed inertia and elasticity will respond to the particular tone called its "fundamental" and to all other tones whose periods are aliquot parts of the periods of that fundamental; but it is not with such quasi resonance that the present invention is carried into effect, and I wish it understood that I here disclaim any system employing distributed inductance and capacity as a means for tuning the resonant circuits described in this specification.

A general criterion which determines the utility of a coil for tuning a circuit to a particular high frequency is that the potential energy of the displacement-currents in the coil shall be small compared to the kinetic energy of the conduction-current flowing through the coil when the coil is traversed by a current of that frequency.

I have found that for a single-layer coil the following procedure is sufficient for practical purposes: Determine the inductance of the coil by formulæ to be found in the text-books and treatises on electricity and magnetism. This will enable the kinetic energy of the coil to be determined for any particular current and will also permit of the determination of what would be the potential gradient along the coil for the current of the frequency to be employed if the coil were devoid of distributed electrostatic capacity. Next calculate the electrostatic capacity between an end turn and each of the remaining turns of the coil. These capacities, together with the potential gradient found, will enable the potential energy to be determermened, and if the ratio of the potential energy to the kinetic energy so found be neglible compared to unity the coil will practically satisfy the requirements hereinbefore mentioned. If the coil does not meet the requirements, the design should be so changed as to increase the separation between the turns, or the size of the wire should be diminished or the dimensions of the coil so otherwise altered as to decrease the distributed capacity without proportionately diminishing the inductance. The calculations may be greatly abbreviated and the liability to error greatly reduced if the results of the computations be plotted in curves.

Regarding the effect of a dielectric core in a coil to be used for tuning a circuit to a high frequency it is sufficient to state that the preferred form of support for such a coil is any skeleton frame which will hold the turns of wire in place without exposing much surface of contact to the wires and affording a minimum of opportunity for the development of displacement-currents within itself.

In this specification I have spoken of elevated conductors, vertically-elevated conductors, and vertical conductors. I wish to be understood as including in the term "elevated" conductors disposed at an angle to the earth's surface as distinguished from horizontal conductors disposed parallel to the earth's surface. By the terms "vertically-elevated" and "vertical" I refer to conductors whose disposition with regard to the earth's surface is mainly or wholly at a right angle or vertical thereto, which is the particular form of elevated conductor preferred by me for use in connection with my present improvement.

In this specification I have described the development of free or unguided electromagnetic signal-waves of a given frequency by employing in association with an elevated conductor a circuit such as to produce therein forced simple harmonic electric vibrations of the frequency desired. I have also described a method of receiving or absorbing the energy of free or unguided simple harmonic electromagnetic waves of one frequency to the exclusion of waves of a different frequency by associating with an elevated conductor a circuit made resonant to the frequency of the waves whose energy is to be absorbed. The circuit whereby forced simple harmonic electric vibrations are produced in the elevated conductor I have shown as a circuit containing a condenser and a self-induction coil so proportioned as to make the natural vibrations of a frequency which is the frequency of the vibrations to be forced or impressed in an elevated conductor. The circuit whereby the energy of the electromagnetic waves of one frequency is absorbed to the exclusion of that of waves of other frequencies is in like manner a circuit containing a condenser and a self-induction coil so proportioned as to make the circuit resonant to a frequency which is the frequency of the waves the energy of which is to be received. Both of the circuits I have spoken of are tuned circuits, and they may be conveniently distinguished with reference to their respective functions by denominating the circuit employed in the development of the vibrations

as an "oscillating" or "sonorous" circuit and by denominating the circuit employed in the reception or absorption of the vibrations as a "resonant" circuit. I prefer to make this discrimination in nomenclature for the reason that while both the circuits are resonant circuits, yet functionally only that one employed for receiving or absorbing is accurately so described. Except for this distinction in function it is well to note that all oscillating or sonorous circuits are resonant circuits, but only such resonant circuits as have their resistance less than the square foot of the ratio of four times their inductance by their capacity are oscillating or sonorous circuits.

Also throughout this specification I have described the electrical oscillations or vibrations and the *free or* unguided electromagnetic waves or radiations as simple harmonic. It is the object of my present invention to approach as nearly as possible to the perfect simple harmonic wave, and such object is attained to within such a degree of precision as to preclude any interference with the operation of the system by any possible departure that may exist in the wave from the absolute simple harmonic form. My reason for confining the description of the electrical oscillations or vibrations and the electromagnetic waves or vibrations to the simple harmonic type is that in the operation of the system only the simple harmonic components are effective in carrying out the object of the invention. Though it is impossible to prevent the presence of minute overtones accompanying these simple harmonic waves, such overtones not only do not contribute to the useful operation of the system, but may, in fact, become obstacles to such useful and complete operation unless their amplitude be excessively small, as is the case in the present invention. It is for this reason that I have taken every precaution to approximate as closely as may be to the true or absolute simple harmonic wave form, thereby reducing to a minimum the overtones which cause a departure from the true sine-wave

Specifically, though it may be possible to employ the purposes of multiple and selective wireless telegraphy, electric vibrations and radiations departing considerably from the simple harmonic type by employing at the receiving end circuits selective to the fundamental of such vibrations and radiations, yet it will only be through the selective reception of that simple harmonic component of the vibrations or radiations which is their fundamental that the system will be operative. The other simple harmonic components of the vibrations or radiations add nothing to the operation of the system. Moreover, if such overtones exist in the waves emanating from a transmitting-station their presence will preclude the possibility of placing receiving-stations in the immediate neighborhood of such transmitting-station for the reception of signal-waves of frequencies corresponding to the frequencies of such overtones.

Whereas in the present specification I have used the term "elevated" conductor to describe the source of radiation of electromagnetic waves developed by forced electric vibrations impressed thereon, yet I deem it proper to point out that this expression should not be confused with the term "conductor" when used in connection with systems wherein that term is employed to denote a wire or other metallically-continuous conductor extending from a transmitting to a receiving station. It is of course obvious that in the art to which the present specification relates such a conductor is wholly absent. The vertical metallically-continuous source of radiant energy is a structure the location and function of which are confined entirely to the transmitting or it may be the receiving end of a system in which the conductor which connects the transmitting and receiving stations is the non-metallic—non-conducting, in fact—dielectric medium, which is commonly called the "ether" and which is by many assumed to be essential to the theory of the propagation of electrical and magnetic force, radiant light, and radiant heat.

Having described my invention, I claim—

1. The method of developing free or unguided simple harmonic electromagnetic waves of a definite frequency, which consists in producing forced simple harmonic electric vibrations of the same frequency in an elevated conductor.

2. The method of absorbing the energy of free or unguided, simple harmonic, electromagnetic signal-waves of one frequency, to the exclusion of the energy of like waves of a different frequency, which consists in associating with an elevated conductor a circuit resonant to the frequency of the waves, the energy of which is to be absorbed.

3. The method of distributing the energy of free or unguided electromagnetic waves which consists in independently developing forced simple harmonic electric vibrations of different frequencies in an elevated conductor and receiving the several energies of the resulting electromagnetic waves of different frequencies, each to the exclusion of the rest, in a separate electric translating device.

4. The method of distributing the energy of free or unguided electromagnetic waves which consists in independently developing a number of forced simple harmonic electric vibrations of different frequencies in an elevated conductor and receiving the several energies of the resulting electromagnetic waves, of different frequencies, each to the exclusion of the rest, in a separate circuit resonant to the same frequency as that of the waves, the energy of which is to be absorbed therein.

5. The method of distributing the energy of free or unguided electromagnetic waves which consists in developing forced simple

harmonic electric vibrations of different frequencies, each in a different elevated conductor, and receiving the several energies of the resulting electromagnetic waves of different frequencies, each to the exclusion of the rest, in a separate electric translating device.

6. The method of distributing the energy of free or unguided electromagnetic waves which consists in developing a number of forced simple harmonic electric vibrations of different frequencies, each in a different elevated conductor, and receiving the several energies of the resulting electromagnetic waves of different frequencies, each to the exclusion of the rest, in a separate resonant circuit attuned to the same frequency as that of the waves, the energy of which is to be absorbed therein.

7. The method of rendering a circuit resonant to a given high frequency, which consists in balancing the reactance of an air-condenser by the reactance of a coil, the amplitude of whose potential energy is small compared to the amplitude of its kinetic energy when it is supporting a current of said given high frequency.

8. The method of constructing a coil to be used in a circuit to be made resonant to a given high frequency, which consists in so proportioning the coil that the amplitude of its potential energy shall be small compared to the amplitude of its kinetic energy when supporting a current of given high frequency.

9. The method of developing free or unguided simple harmonic electromagnetic signal-waves, which consists in discharging a condenser through a closed circuit having inductance adapted to produce under such conditions simple harmonic vibrations, and impressing the electrical vibrations so produced upon an open-circuit or elevated conductor substantially as described.

10. The method of developing free or unguided simple harmonic electromagnetic signal-waves which consists in discharging a condenser through a closed circuit having inductance adapted to produce under such conditions simple harmonic vibrations, impressing these vibrations on a resonant circuit or group thereof resonant to the frequency of these vibrations, and impressing the resulting electrical vibrations upon an open-circuit or elevated conductor.

11. The method of selectively receiving the energy of free or unguided simple harmonic electromagnetic signal-waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in an elevated conductor and translating or conveying the several energies of the resulting electrical oscillations, each to a separate circuit associated with said elevated conductor, and resonant to the frequency of the electromagnetic waves, the energy of which it is to receive.

12. The method of selectively receiving the energy of simple harmonic electromagnetic signal-waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in an elevated conductor and translating or conveying the several energies of the resulting electrical oscillations, each to a separate group of resonant circuits associated with said elevated conductor and resonant to the frequency of the electromagnetic waves the energy of which it is to receive.

13. The method of selectively receiving the energy of free or unguided simple harmonic electromagnetic signal-waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in a plurality of elevated conductors, thereby developing in each elevated conductor electrical oscillations corresponding in frequency to the electromagnetic waves received by it and in translating or conveying from each elevated conductor to an associated circuit the energy of the particular electrical oscillation to the frequency of which said associated circuit is made resonant.

14. The method of selectively receiving the energy of simple harmonic electromagnetic signal-waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in a plurality of elevated conductors, thereby developing in each elevated conductor electrical oscillations corresponding in frequency to the electromagnetic waves received by it and in translating or conveying from each elevated conductor to a group of resonant circuits associated therewith the energy of the particular electrical oscillations to the frequency of which said group of associated circuits is resonant.

15. The method of absorbing the energy of free or unguided simple harmonic electromagnetic signal-waves of one frequency to the exclusion of the energy of like waves of different frequencies which consists in associating with an elevated conductor a group of circuits, each resonant to the frequency of the waves, the energy of which is to be absorbed.

16. The method of receiving the energy of simple harmonic electromagnetic signal-waves, which consists in receiving the same in an elevated conductor and translating or conveying the energy of the resulting electrical oscillations to an electrical translating device shunted around the terminals of one of the elements of a resonant circuit associated with said elevated conductor and resonant to the frequency of the electromagnetic waves

17. The method of distributing the energy of free or unguided electromagnetic waves, which consists in independently developing a number of forced simple harmonic electric vibrations of different frequencies in an elevated conductor and receiving the several energies of the resulting electromagnetic waves of different frequencies, each to the exclusion

of the rest, in a group of circuits resonant to the same frequency as that of the waves the energy of which is to be absorbed therein.

18. The method of distributing the energy of free or unguided electromagnetic waves, which consists in developing a number of forced simple harmonic electric vibrations of different frequencies each in a different elevated conductor, and receiving the several energies of the resulting electromagnetic waves of different frequencies, each to the exclusion of the rest, in a separate group of circuits resonant to the same frequency as that of the waves the energy of which is to be absorbed.

19. The method of developing free or unguided simple harmonic electromagnetic signal waves, which consists in disturbing the electrical equilibrium of a circuit comprising a condenser, and a coil having inductance adapted to produce under such conditions simple harmonic vibrations, and impressing the electrical vibrations so produced upon an open circuit or elevated conductor, substantially as described.

20. The method of developing free or unguided simple harmonic electromagnetic signal-waves, which consists in disturbing the electrical equilibrium of a circuit comprising a condenser and a coil having inductance adapted to produce under such conditions simple harmonic vibrations, impressing these vibrations on a resonant circuit or group thereof attuned to the frequency of these vibrations, and impressing the resulting electrical vibrations upon an open circuit or elevated conductor.

21. The method of receiving the energy of simple harmonic electromagnetic signal waves, which consists in receiving the same in an elevated conductor and translating or conveying the energy of the resulting electrical oscillations to an electrical translating device forming one of the elements of a resonant circuit associated with said elevated conductor and resonant to the frequency of the electromagnetic waves.

22. The method of developing free or unguided simple harmonic electromagnetic signal waves or radiations, which consists in disturbing the electrical equilibrium of a closed oscillating circuit associated with an elevated conductor and possessing sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the elevated conductor.

23. The method of developing free or unguided simple harmonic electromagnetic signal waves or radiations, which consists in disturbing the electrical equilibrium of a closed oscillating circuit forming one of a group of resonant circuits associated with an elevated conductor, each circuit of the group possessing sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the other circuits of the group and between it and the elevated conductor.

24. The method of developing free or unguided simple harmonic electromagnetic signal waves or radiations, of different frequencies independently in a single elevated conductor, which consists in disturbing the electrical equilibrium of closed oscillating circuits associated with said elevated conductor, each being attuned to a different one of the frequencies to be developed, and each of said oscillating circuits having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the other oscillating circuits and the said elevated conductor.

25. The method of receiving the energy of simple harmonic electromagnetic waves of a given frequency, to the exclusion of the waves of different frequencies, which consists in receiving the same in an elevated conductor and conveying the energy of the resulting electrical oscillations to a circuit associated with the elevated electrical conductor and made resonant to the frequency of the electromagnetic waves the energy of which is to be received by a condenser and an auxiliary inductance-coil whose inductance is sufficient to swamp the effect of the mutual inductance between the associated circuit and the elevated conductor.

26. The method of selectively receiving the energy of simple harmonic electromagnetic signal waves of one frequency, to the exclusion of like waves of different frequencies, which consists in receiving the same in an elevated conductor and translating or conveying the energies of the resulting electrical oscillations each to a separate circuit associated with said elevated conductor and resonant to the frequency of the electromagnetic waves, the energy of which is to be received, and each having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the other associated circuits and between it and the elevated conductor.

27. The method of developing simple harmonic electromagnetic signal waves or radiations of a given frequency, which consists in impressing upon a freely-radiating vertical oscillator forced simple harmonic electrical oscillations of the same frequency.

28. The method of simultaneously developing simple harmonic electromagnetic waves or radiations of different frequencies, which consists in independently impressing upon a freely-radiating vertical oscillator forced simple harmonic electrical oscillations of the same frequencies.

29. The method of absorbing the energy of free or unguided simple harmonic electromagnetic signal waves of one frequency to the exclusion of the energy of like waves of different frequency, which consists in [illegible]

effect of the mutual inductance between it and the elevated conductor.

30. The method of distributing the energy of free or unguided, electromagnetic waves, which consists in independently developing a number of forced, simple harmonic, electric vibrations of different frequencies in an elevated conductor, and receiving the several energies of the resulting electromagnetic waves of different frequencies, each to the exclusion of the rest in a separate circuit resonant to the same frequency as that of the waves, the energy of which is to be absorbed, and having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all of the circuits with which it is associated.

31. The method of distributing the energy of free or unguided, electromagnetic waves, which consists in developing a number of forced, simple harmonic, electric vibrations of different frequencies, each in a different elevated conductor, and receiving the several energies of the resulting electromagnetic waves of different frequencies, each to the exclusion of the rest, in a separate resonant circuit attuned to the same frequency as that of the waves, the energy of which is to be absorbed therein, and having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

32. The method of developing free or unguided, simple harmonic, electromagnetic signal-waves, which consists in discharging a condenser through a closed circuit having inductance adapted to produce under such conditions simple harmonic vibrations and sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and an elevated conductor with which it is associated, and impressing the electrical vibrations so produced upon the said elevated conductor.

33. The method of developing free or unguided, simple harmonic, electromagnetic, signal-waves, which consists in discharging a condenser through a closed circuit having inductance adapted to produce under such conditions simple harmonic vibrations, impressing these vibrations on a resonant circuit or group thereof resonant to the frequency of these vibrations, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated, and impressing the resulting electrical vibrations upon an open circuit or elevated conductor.

34. The method of selectively receiving the energy of free or unguided, simple harmonic, electromagnetic, signal-waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in an elevated conductor and translating or conveying the several energies of the resulting electrical oscillations, each to a separate circuit associated with said elevated conductor, and resonant to the frequency of the electromagnetic waves, the energy of which it is to receive, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

35. The method of selectively receiving the energy of simple harmonic, electromagnetic, signal-waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in an elevated conductor and translating or conveying the several energies of the resulting electrical oscillations, each to a separate group of resonant circuits associated with said elevated conductor and resonant to the frequency of the electromagnetic waves, the energy of which it is to receive, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

36. The method of selectively receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in a plurality of elevated conductors, thereby developing in each elevated conductor electrical oscillations corresponding in frequency to the electromagnetic waves received by it and in translating or conveying from each elevated conductor to an associated circuit the energy of the particular electrical oscillations to the frequency of which said associated circuit is made resonant, each of said circuits having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the elevated conductor and all circuits with which it is associated.

37. The method of selectively receiving the energy of simple harmonic, electromagnetic, signal-waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in a plurality of elevated conductors, thereby developing in each elevated conductor electrical oscillations corresponding in frequency to the electromagnetic waves received by it and in translating or conveying from each elevated conductor to a group of resonant circuits associated therewith the energy of the particular electrical oscillations to the frequency of which said group of associated circuits is resonant, each of said circuits having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the elevated conductor and all circuits with which it is associated.

38. The method of absorbing the energy of free or unguided, simple harmonic, electromagnetic, signal-waves of one frequency to the exclusion of the energy of like waves of different frequencies, which consists in associating with an elevated conductor a group of circuits, each resonant to the frequency of the waves, the energy of which is to be absorbed, each circuit having sufficient auxiliary inductance to swamp the effect of the

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mutual inductance between it and all circuits with which it is associated.

39. The method of receiving the energy of simple harmonic, electromagnetic signal-waves, which consists in receiving the same in an elevated conductor and translating or conveying the energy of the resulting electrical oscillations to an electrical translating device shunted around the terminals of one of the elements of a resonant circuit associated with said elevated conductor and resonant to the frequency of the electromagnetic waves, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

40. The method of distributing the energy of free or unguided electromagnetic waves, which consists in independently developing a number of forced, simple harmonic, electric vibrations of different frequencies in an elevated conductor and receiving the several energies of the resulting electromagnetic waves of different frequencies, each to the exclusion of the rest, in a group of circuits resonant to the same frequency as that of the waves, the energy of which is to be absorbed therein, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

41. The method of distributing the energy of free or unguided electromagnetic waves, which consists in developing a number of forced, simple harmonic, electric vibrations of different frequencies, each in a different elevated conductor, and receiving the several energies of the resulting electromagnetic waves of different frequencies, each to the exclusion of the rest, in a separate group of circuits resonant to the same frequency as that of the waves the energy of which is to be absorbed, each of said circuits having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the elevated conductor and all circuits with which it is associated.

42. The method of developing free or unguided, simple harmonic, electromagnetic signal-waves, which consists in disturbing the electrical equilibrium of a circuit comprising a condenser, and a coil having inductance adapted to produce under such conditions simple harmonic vibrations, and impressing the electrical vibrations so produced upon an elevated conductor, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

43. The method of developing free or unguided, simple harmonic, electromagnetic signal-waves, which consists in disturbing the electrical equilibrium of a circuit comprising a condenser and a coil having inductance adapted to produce under such conditions simple harmonic vibrations, impressing these vibrations on a resonant circuit or group thereof attuned to the frequency of these vibrations, and impressing the resulting electrical vibrations upon an elevated conductor each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

44. The method of receiving the energy of simple harmonic, electromagnetic signal-waves, which consists in receiving the same in an elevated conductor and translating or conveying the energy of the resulting electrical oscillations to an electrical translating device forming one of the elements of a resonant circuit associated with said elevated conductor and resonant to the frequency of the electromagnetic waves, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

45. The method of absorbing the energy of free or unguided simple harmonic electromagnetic signal-waves of one frequency, to the exclusion of the energy of like waves of different frequency, which consists in receiving the same in an elevated conductor and translating or conveying the resulting electric vibrations to a circuit associated with said elevated conductor, and resonant to the frequency of the waves, the energy of which is to be received.

In testimony whereof I have hereunto subscribed my hand this 6th day of February, 1900.

JOHN STONE STONE.

Witnesses:
E. D. CHADWICK,
ALEX. P. BROWNE.

No. 714,756.

Patented Dec. 2, 1902.

J. S. STONE.

METHOD OF SELECTIVE ELECTRIC SIGNALING.

(Application filed Feb. 8, 1900.)

(No Model.)

5 Sheets—Sheet 1.

Fig 1.

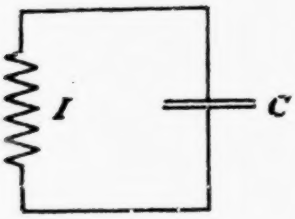


Fig. 2.

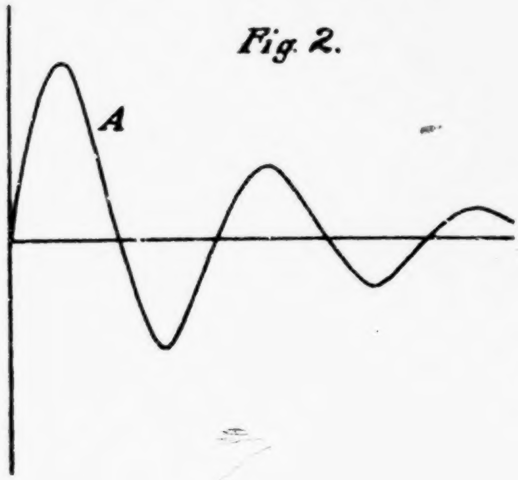
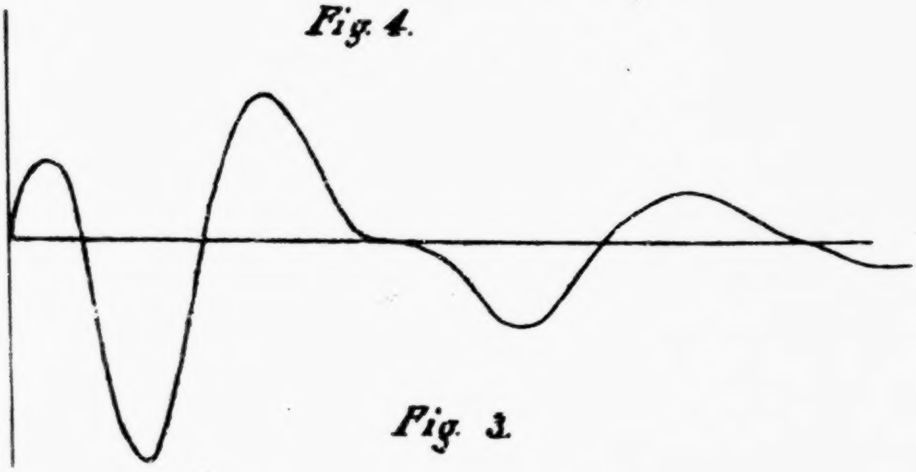


Fig. 4.



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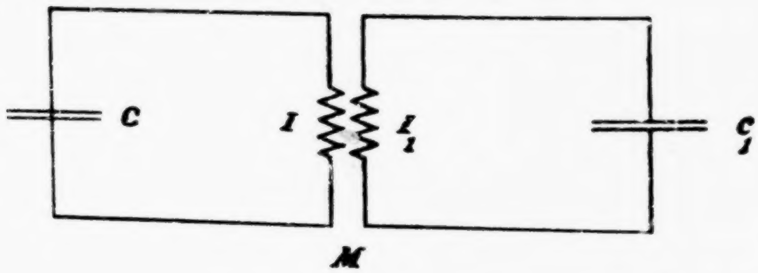

WITNESSES:

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No. 714,756. Patented Dec. 2, 1902.

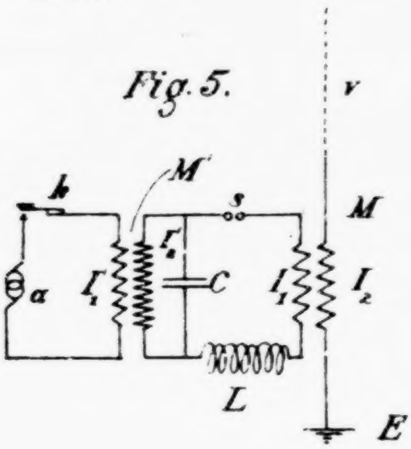
J. S. STONE.

METHOD OF SELECTIVE ELECTRIC SIGNALING.

Application filed Feb. 8, 1900.)

(No Model.) 5 Sheets—Sheet 2.

Fig. 5.



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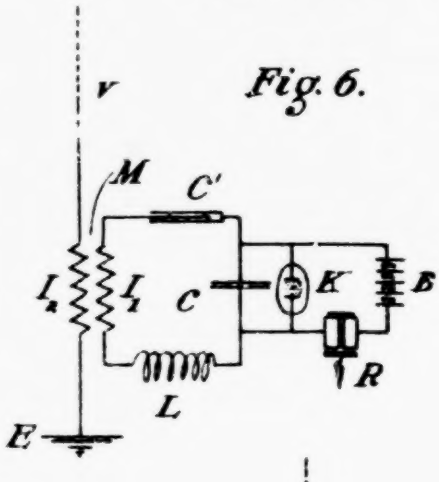

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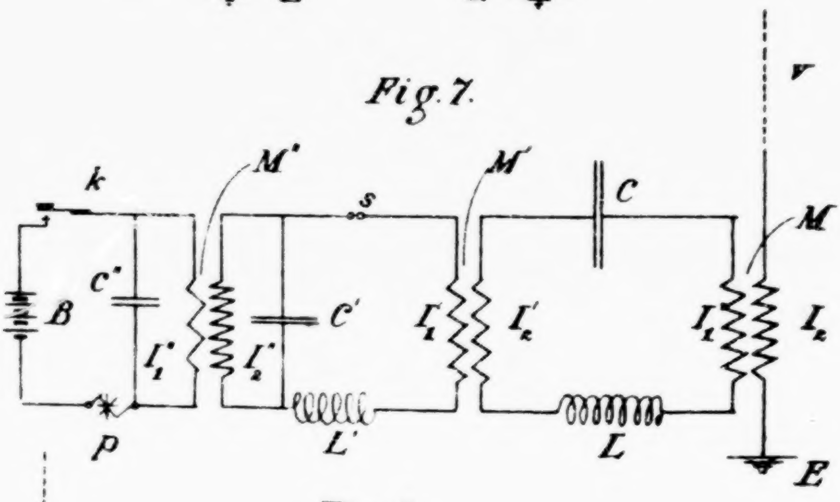

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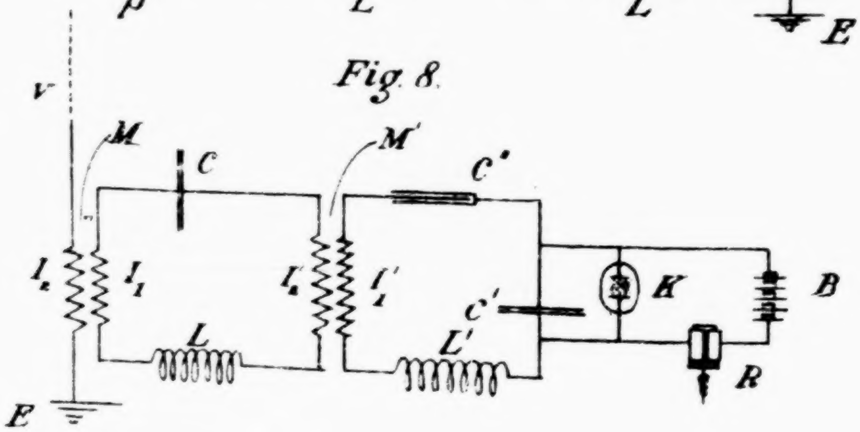

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Fig. 9.

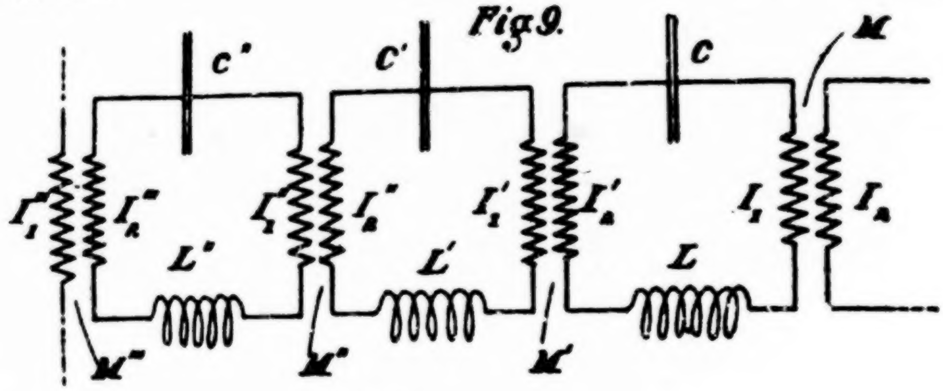


Fig. 10.

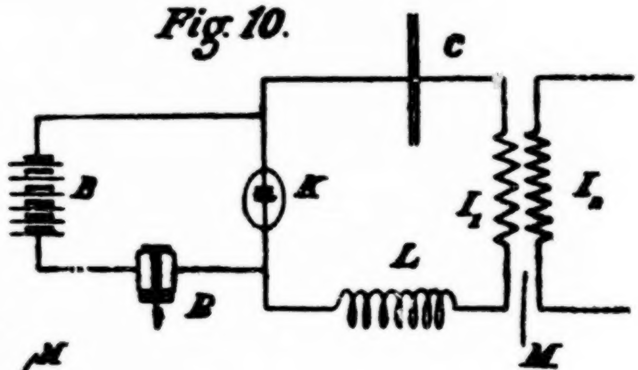
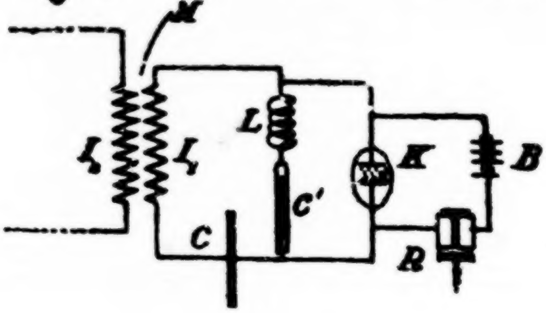


Fig. 11.



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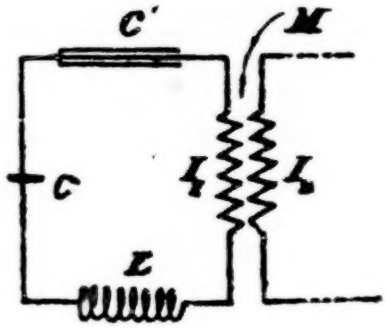

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3665

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METHOD OF SELECTIVE ELECTRIC SIGNALING.

(Application filed Feb. 8, 1900.)

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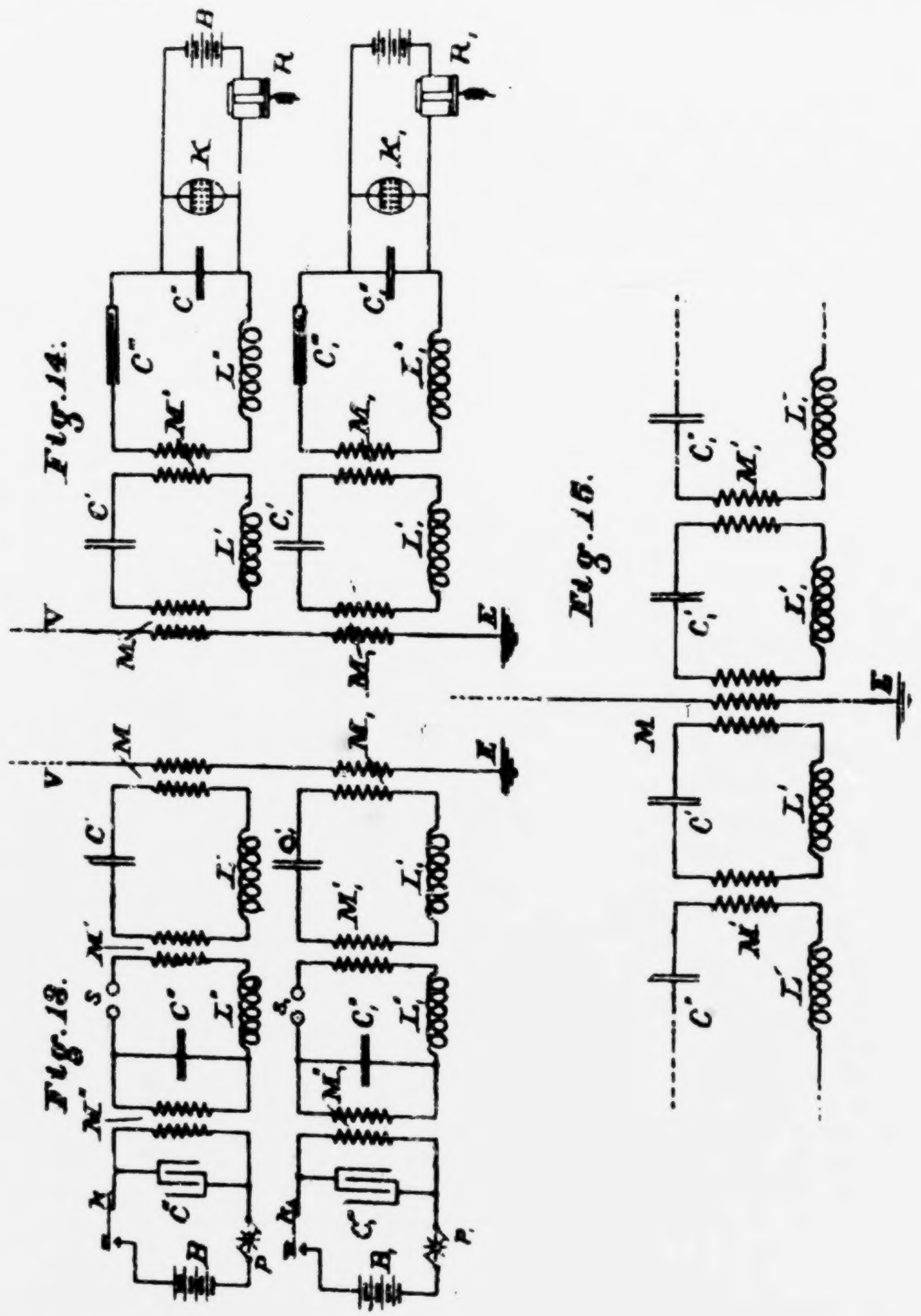

WITNESSES

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No. 714,756. Patented Dec. 2, 1902.

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(Application filed Feb. 8, 1900.)

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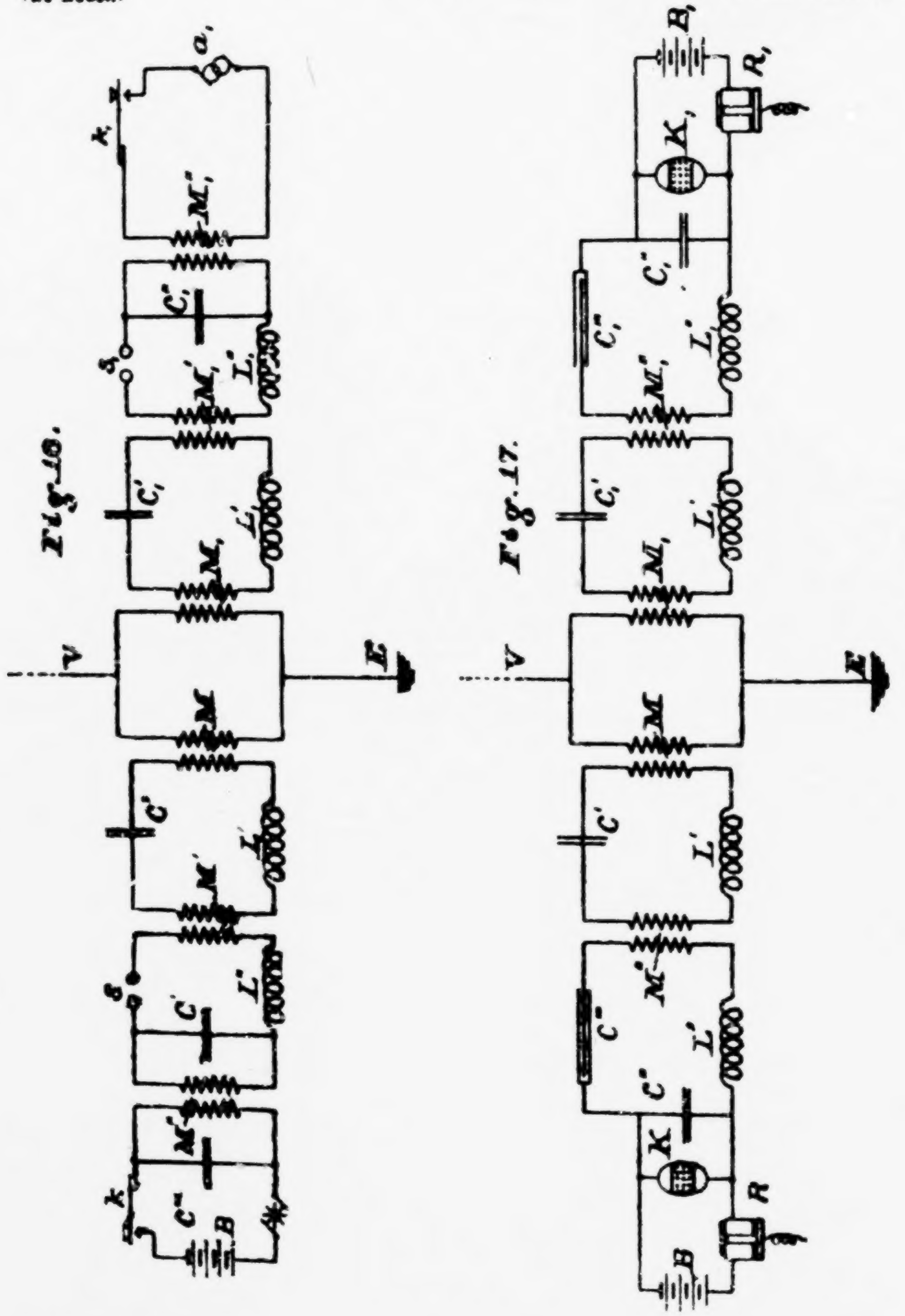

WITNESSES.

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3229-3230

Defendant's Exhibit Q-3 3667

No. 714,831. Patented Dec. 2, 1902.

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APPARATUS FOR SELECTIVE ELECTRIC SIGNALING.

Application filed Jan. 23, 1901.

(No Model.) 5 Sheets—Sheet 1.

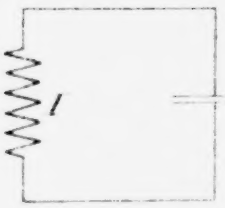

Fig 1.

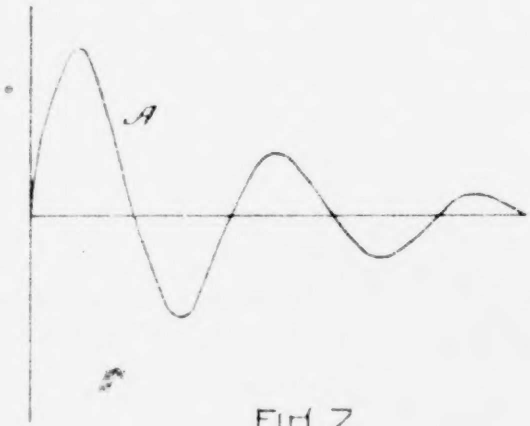

Fig 2.

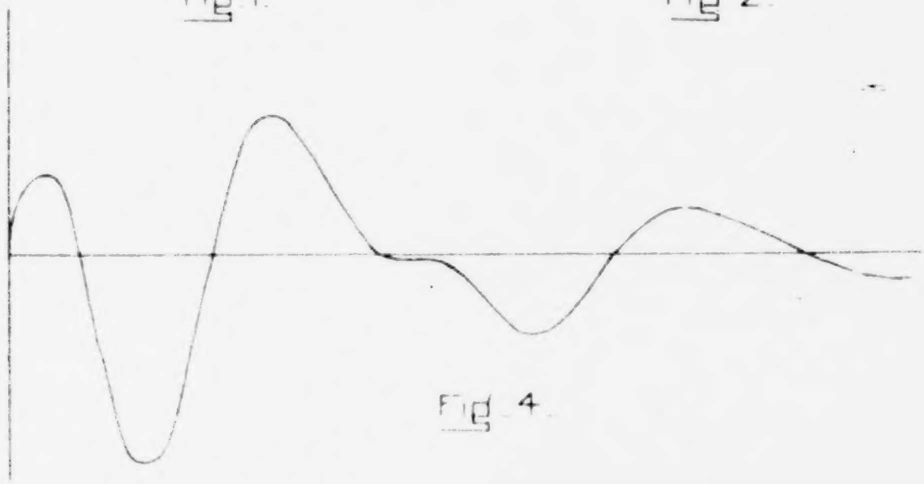

Fig 4.

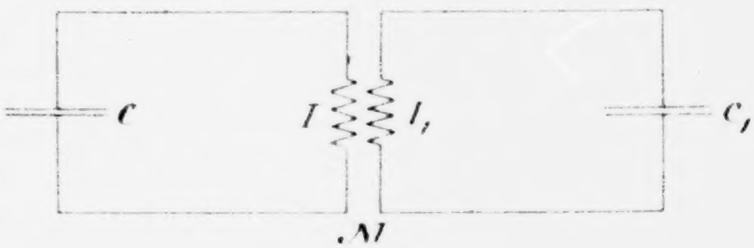

Fig 3.

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APPARATUS FOR SELECTIVE ELECTRIC SIGNALING.

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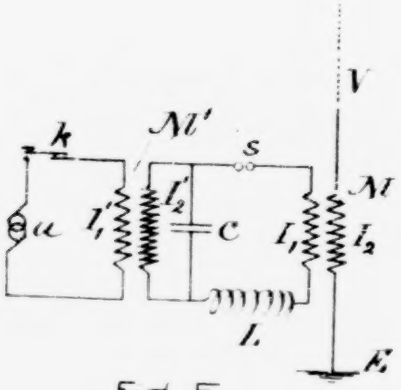

Fig. 5.

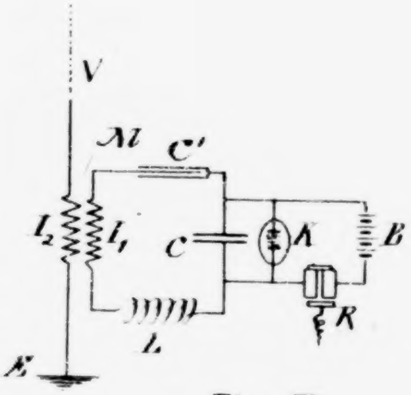

Fig. 6.

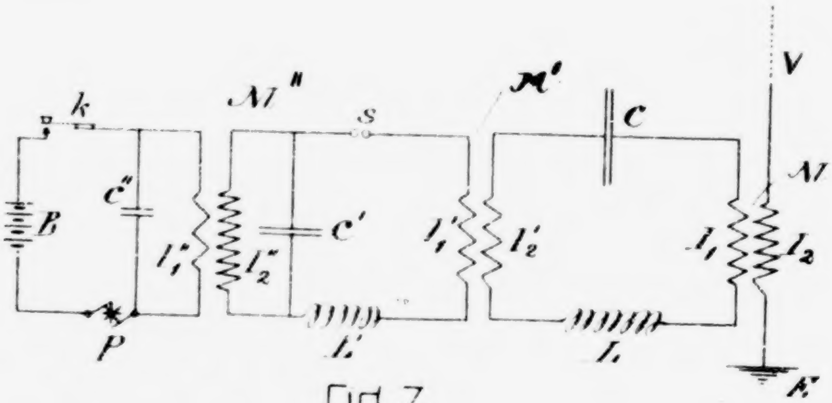

Fig. 7.

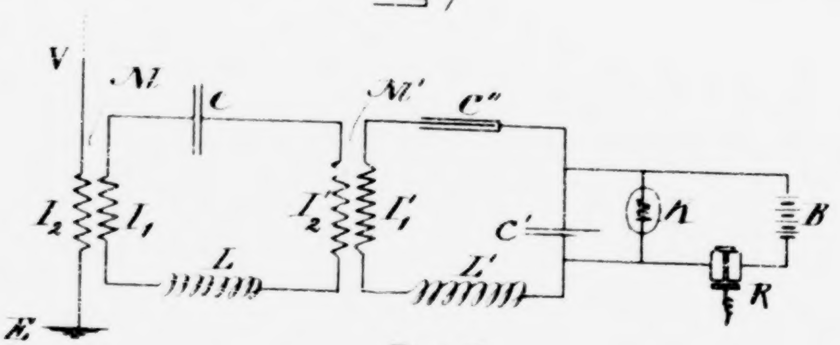

Fig. 8.

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APPARATUS FOR SELECTIVE ELECTRIC SIGNALING.

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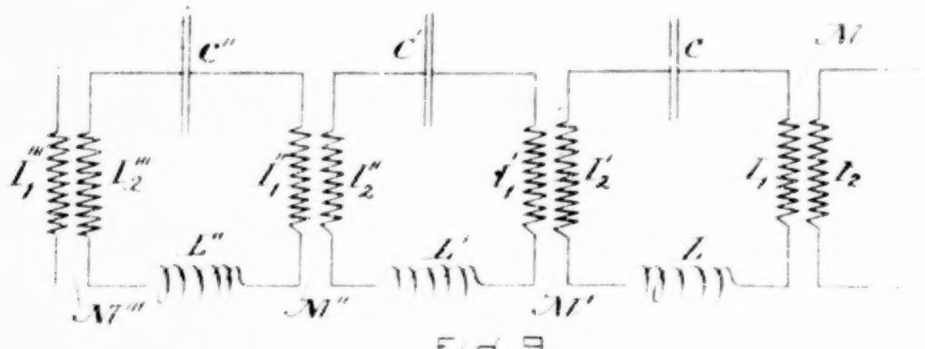

Fig. 9.

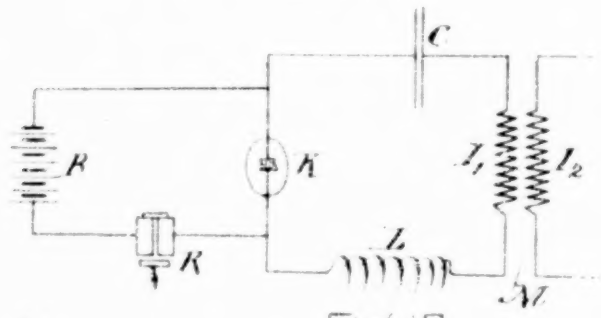

Fig. 10.

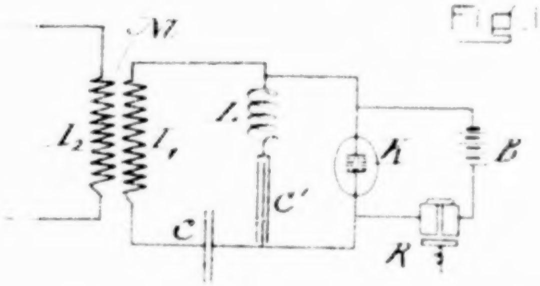

Fig. 11.

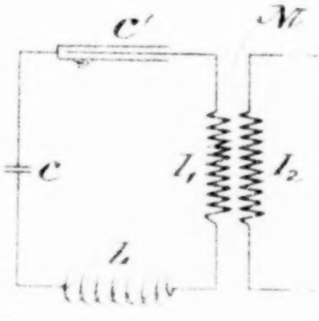

Fig. 12.

WITNESSES:

[illegible]

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Attorney

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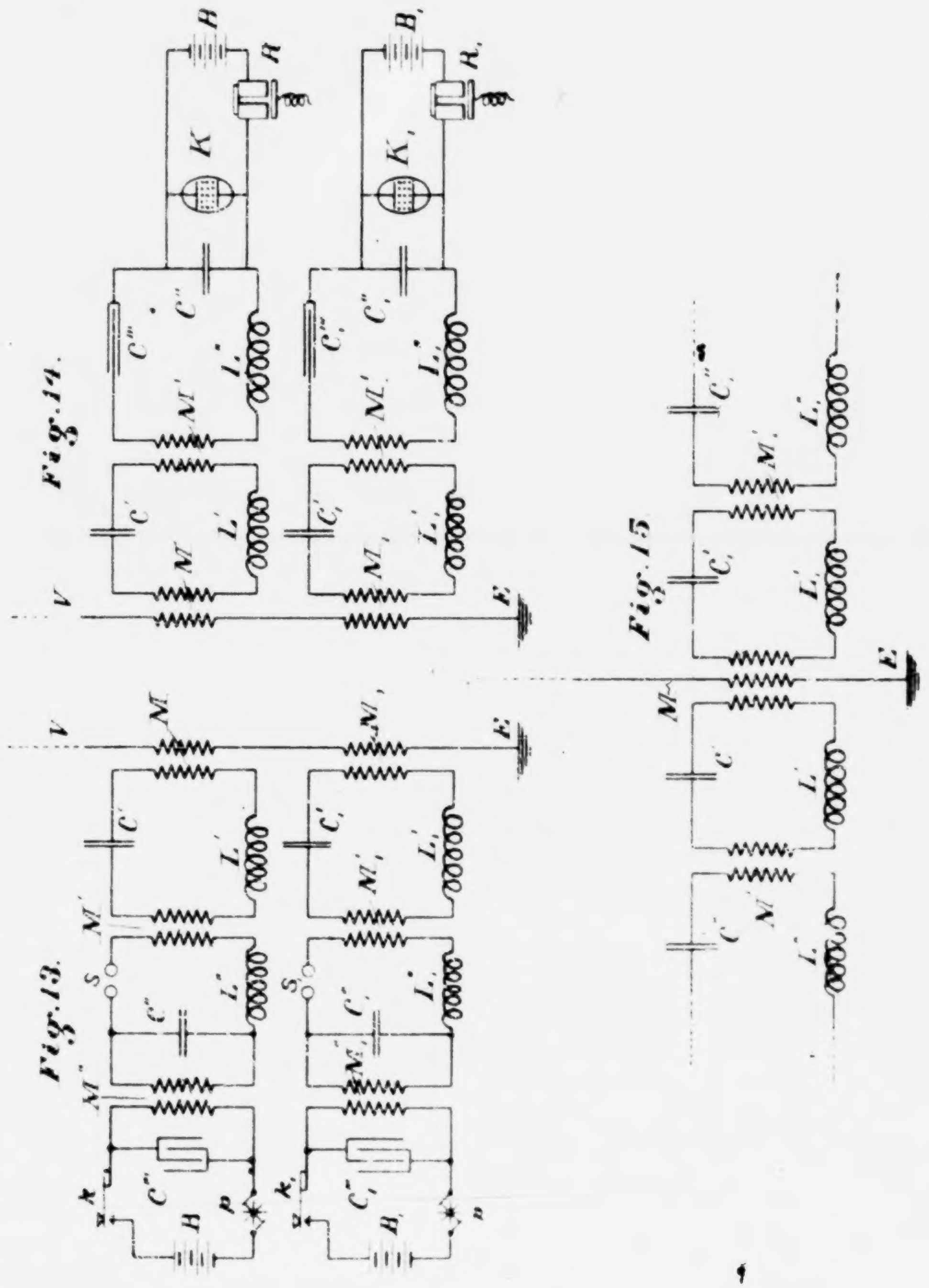

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L. A. Jones

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APPARATUS FOR SELECTIVE ELECTRIC SIGNALING.

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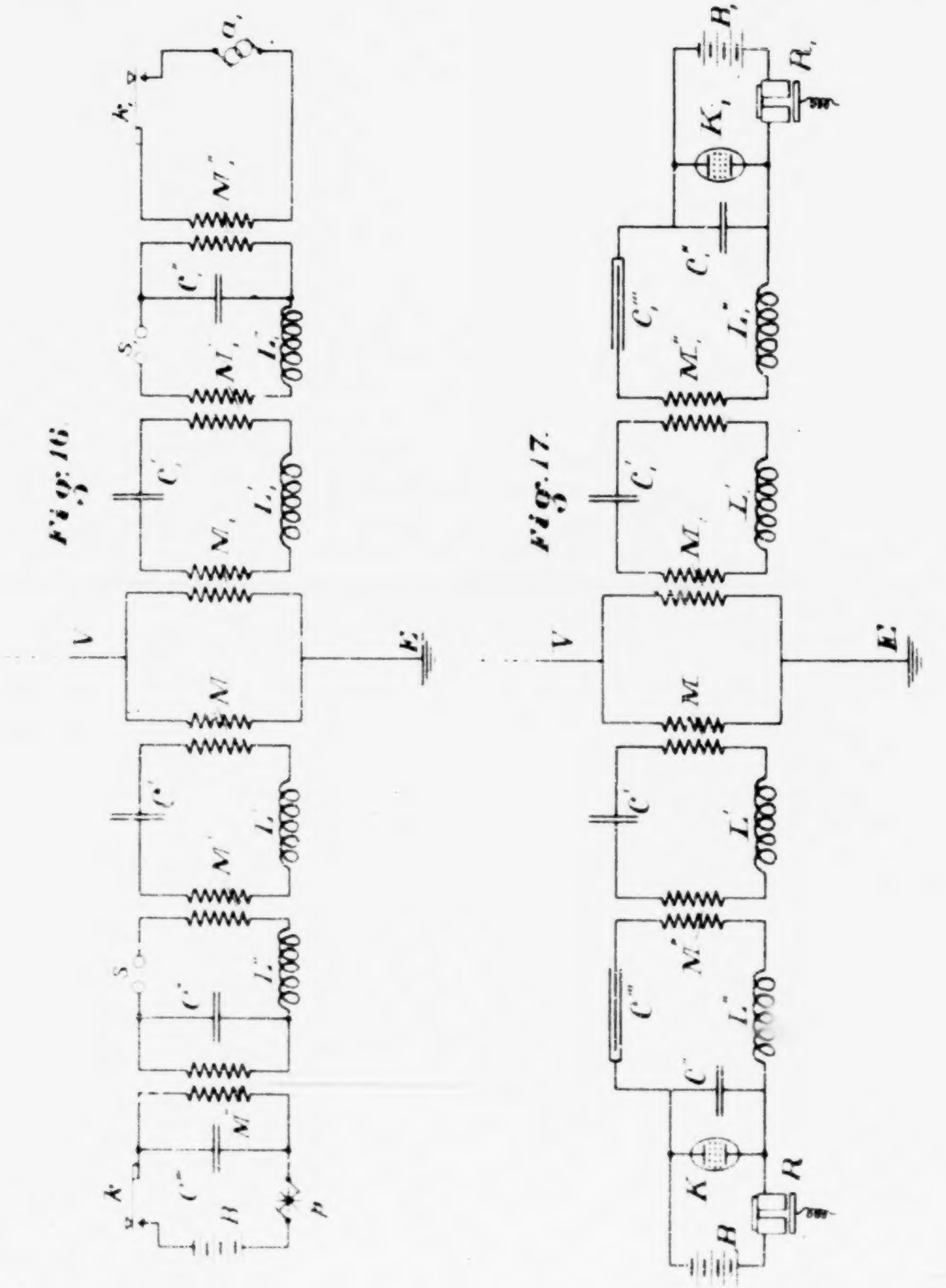

WITNESSES

INVENTOR.

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by Alex P Browne, attorney

UNITED STATES PATENT OFFICE.

JOHN STONE STONE, OF BOSTON, MASSACHUSETTS, ASSIGNOR TO LOUIS E. WHICHER, ALEXANDER P. BROWNE, AND BRAINERD T. JUDKINS, TRUSTEES.

APPARATUS FOR SELECTIVE ELECTRIC SIGNALING.

SPECIFICATION forming part of Letters Patent No. 714,831, dated December 2, 1902.

Original application filed February 8, 1900, Serial No. 4,505. Divided and this application filed January 23, 1901. Serial No. 44,384. (No model.)

To all whom it may concern:

Be it known that I, JOHN STONE STONE, a citizen of the United States, residing at Boston, in the county of Suffolk and State of Massachusetts, have invented certain new and useful Improvements in Apparatus for Selective Electric Signaling, of which the following is a specification.

My invention relates to the art of transmitting intelligence from one station to another by means of electromagnetic waves without the use of wires to guide the waves to their destination, and it relates more particularly to the system of such transmission in which the electromagnetic waves are developed by producing electric vibrations in an elevated conductor, preferably vertically elevated.

Heretofore in signaling between two stations by means of electromagnetic waves when the stations are not connected by a conducting-wire certain disadvantageous limitations have been observed which greatly militated against the commercial value of the methods employed. When the electromagnetic waves are developed by producing natural or forced electric vibrations in a horizontal conductor, the attenuation of the waves so developed as they travel away from the conductor is found to be so great as to very seriously limit the distance to which they may be transmitted and effectively received, the chief cause of this observed phenomenon probably being that owing to the horizontal position of the conductor the plane of polarization of the waves is such as to cause the rapid absorption of the energy of the waves by the conducting surface of the earth or water over which they travel. This difficulty has been overcome by a method of developing the waves which consists in producing natural electric vibrations in a vertically-elevated conductor, in which case the plane of polarization of the wave so produced is at quadrature with that of the waves which may be developed in a horizontal wire, and in case of the vertical conductor the attenuation of the waves is observed to be very much less than in the case of the horizontal conductor, so that these waves may be transmitted to and effectively received at much greater distances. A limitation of the commercial utility of this system is, however, observed, which depends upon the fact that it has not heretofore been found possible, so far as I am aware, to direct signals sent out from a transmitter-station to the particular receiving-station with which it is desired to communicate to the exclusion of other receiving-stations equipped with equally or more sensitive receiving apparatus and located within the radius of influence of the sending-station. Electromagnetic waves have also been developed by producing natural or forced electric oscillations in loops or coils of wire at the transmitting-station and also by means of the discharge of electricity between two conducting spheres, cylinders, or cones; but in such cases the sphere of influence is so limited as to greatly restrict the commercial utility of these two methods of developing the signal-waves. In fine, the method of signaling by means of electromagnetic waves between stations not connected by a conducting wire, in which method the electromagnetic waves are developed by electric vibrations in an elevated conductor, has great advantages over the other existing or proposed methods for accomplishing this purpose in which the electromagnetic waves are developed by other means, since in the case of the waves developed by the elevated conductor method the waves may be transmitted to and effectively received at greater distances than by the other systems; but whereas in the systems employing the other methods of generating the waves the signals developed may at least theoretically be directed to the particular receiving-station with which it is desired to communicate to the exclusion of other similar receiving-stations in the neighborhood. It has heretofore been found impossible, so far as I know, to accomplish this purpose in the system employing an elevated conductor or wire as the source of the electromagnetic waves.

The object of this invention is to overcome

the hereinbefore-described limitation to the system in which the waves emanate from vertical conductors, so that in such systems the transmitting-stations may selectively transmit their signals each to a particular receiving station simultaneously or otherwise without mutual interference.

It is also the object of the invention to provide means whereby each of a plurality of transmitting and receiving stations in such a system may be enabled to selectively place itself in communication with any other station to the exclusion of all the remaining stations.

It is further the object of the present invention to enable the vertical or elevated conductor in such a system to be made the source of simple harmonic electromagnetic waves of any desired frequency independent of its length and other geometrical constants. Thus the frequency impressed upon the elevated conductor may or may not be the same as the natural period or fundamental of such conductor; but, as will be hereinafter explained, an elevated conductor that is aperiodic may be employed and is best adapted for use when the apparatus is to be used successively for different frequencies, and such aperiodic elevated conductor is likewise the preferred form of elevated conductor when two or more frequencies are to be simultaneously impressed upon or received by a single elevated conductor; but forced simple harmonic electric vibrations of different periodicities may each be separately impressed upon a different elevated conductor, and the several energies of the resulting electromagnetic waves may be selectively conveyed each to a separate translating device.

Before proceeding to describe the invention certain fundamental principles relative to electrical vibrations should be stated, as these principles are involved in the art of signaling by means of what may be called "unguided electromagnetic waves."

If the electrical equilibrium of a conductor be abruptly disturbed and the conductor thereafter be left to itself, electric currents will flow in the conductor, which tend to ultimately restore the condition of electrical equilibrium. These currents may be either unidirectional or oscillatory in character, depending upon the relation between the principal electromagnetic constants of the conductor—i. e., upon its electromagnetic and electrostatic capacities and its resistance. These phenomena are analogous to the mechanical phenomena which are observed when the mechanical equilibrium of a system is abruptly disturbed and the system is thereafter left to itself. In the case of a mechanical system motions result which tend to restore the mechanical equilibrium of the system. These motions may consist either of a unidirectional displacement or of [illegible] vibrations of the system or parts of the system, depending upon the relations which subsist between the principal mechanical constants of the system—i. e., its moments of mass and elasticity and its friction coefficients. In general the determination of the relations which must subsist in order that an oscillatory restoration of equilibrium shall take place either in an electric or in a mechanical system and the determination of the period of these oscillations is very difficult; but in certain simple cases both the determination of the conditions for an oscillatory restoration of equilibrium and of the period of these oscillations is quite simple.

An example of a simple mechanical system capable of an oscillatory restoration of equilibrium is to be found in the torsional pendulum, which consists of a highly-elastic wire fixed at one end and supporting at its other extremity a heavy mass called the "bob." If a torsional stress be imparted to the wire of this pendulum by turning the bob about the axis of the wire and the bob be then abruptly released, the pendulum will in general execute isochronous oscillations about the axis of the suspending-wire in the process of restoration of equilibrium. An example of a simple electrical system capable of an oscillatory restoration of equilibrium is to be found in the case of a circuit consisting simply of a condenser and a coil without iron in its core, as shown in Figure 1 of the accompanying drawings, in which C is a condenser, and I is a coil without iron in its core. If a charge of electricity be imparted to the condenser and if its electrodes be then connected to the coil, as shown in Fig. 1, an isochronous oscillatory current will in general be developed in the circuit in the process of restoration of its electrical equilibrium. Such a simple circuit as that shown in Fig. 1 is known as a system with a "single degree of freedom," and the electric oscillations which it supports when its equilibrium is abruptly disturbed and it is then left to itself are known as the "natural" vibrations or oscillations of the system. These vibrations begin with a maximum of amplitude and gradually die away in accordance with what is known as an "exponential" law and are what are known as "simple harmonic vibrations." They may be represented graphically, as in Fig. 2, in which A is a curve drawn to rectangular coordinates, in which the ordinates represent instantaneous values of current strength and the abscissæ represent times. When two such simple circuits are associated together inductively, as shown in Fig. 3, the system so formed is known as a system of "two degrees of freedom," and in the oscillatory restorations of equilibrium—i. e., in the natural vibrations in such circuits—the currents are in general not simple harmonic in character, but in general consist of the superposition of the simple harmonic currents, as shown in Fig. 4. In general if n simple circuits, as shown in Fig. 5, be asso-

ciated together in a system either by conductive or by inductive connections a system of at least n degrees of freedom results, and the natural oscillations of such a system will therefore consist of the superposition of at least n currents. It is, moreover, a fact that the different simple harmonic components of the oscillations which together constitute the oscillatory restoration of equilibrium of a complex system are in general not the same as those of the separate simple circuits when these circuits are isolated from one another; but the presence of each simple circuit modifies the natural period of each of the other circuits with which it is associated. Thus in a particular case if there be two simple circuits, the first with a natural period of .004 of a second when isolated and the second with a period of .0025 of a second when isolated, these circuits when inductively connected, as shown in Fig. 3, may have an oscillatory restoration of equilibrium, of which the simple harmonic components are .00444 of a second and .00159 of a second, showing that the inductive association of the circuits together has increased the natural period of the high-period circuit and decreased the natural period of the low-period circuit. It is, moreover, to be remembered that during the restoration of electric equilibrium currents of each of the periods are found in each of the circuits of the connected system.

So far we have considered the natural vibrations of electric systems—*i. e.*, the electric vibrations by means of which the electric equilibrium of circuits is restored after it has been abruptly destroyed and the circuits are left to themselves—and we have compared the simple case of such natural vibrations with the corresponding natural mechanical vibrations of mechanical systems. We have seen that simple circuits may have simple harmonic natural electric oscillations and that complex circuits will in general have complex electric oscillations. We have, moreover, seen that the natural period of oscillations depended upon the electromagnetic constants of the circuit in the case of a simple circuit and that each of the periods of oscillation in the case of a complex or of interrelated circuits depended upon the electromagnetic constants of each of the interrelated circuits; but besides the ability to execute natural vibrations or oscillations both electric and mechanical systems are capable of supporting what are termed "forced vibrations," and in the case of forced vibrations the period of the vibration is independent of the electromagnetic constants of the circuit on the one hand and the mechanical constants of the mechanical system on the other hand and depends only upon the period of the impressed force. Thus if a simple harmonic electromotive force be impressed upon a circuit free from hysteresis, whether it be a simple circuit or a complex of simple circuits, the forced vibrations or currents resulting from this impressed force will also be simple harmonic and of the same period as that of the impressed force.

In present systems of signaling by means of electromagnetic waves in which a vertical conductor is employed as the source of electromagnetic radiations the electric oscillations are of the kind hereinbefore described as "natural vibrations," the vertical conductor being charged to a high potential relative to the surrounding earth and permitted to abruptly discharge to earth by means of an electric spark between two ball-electrodes. In such a method of developing the electromagnetic waves the oscillations are necessarily of a complex character, and therefore the resulting electromagnetic waves are of a complex character and consist of a great variety of superimposed simple harmonic vibrations of different frequencies. The vibrations consist of a simple harmonic vibration of lower period than all the others, known as the "fundamental," with a great variety of simple harmonies of higher periodicity superimposed thereon. Similarly the vertical conductor at the receiving station is capable of receiving and responding to vibrations of a great variety of frequencies, so that the electromagnetic waves which emanate from one vertical conductor used as a transmitter are capable of exciting vibrations in any other vertical wire as a receiver, and for this reason any transmitting-station in a system of this character will operate any receiving-station within its sphere of influence, and the messages from the transmitting-station will not be selectively received by the particular receiving-station with which it is desired to communicate, but will interfere with the operation of other receiving-stations within its sphere of influence, thereby preventing them from properly responding to the signals of the transmitting-stations from which they are intended to receive their signals.

By my invention the vertical conductor of the transmitting-station is made the source of electromagnetic waves of but a single periodicity, and the translating apparatus at the receiving-station is caused to be selectively responsive to waves of but a single periodicity, so that the transmitting apparatus corresponds to a tuning-fork, sending but a single simple musical tone, and the receiving apparatus corresponds to an acoustic resonator capable of absorbing the energy of that single simple musical tone only. When, however, the elevated conductor is aperiodic, it is adapted to receive or transmit all frequencies, and accordingly a single aperiodic elevated conductor may be associated with a plurality of local circuits each attuned to a different frequency after the manner now well known in the art of multiple telegraphy by wire conductors.

When a single elevated conductor is to be made a source of a plurality of single waves

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of different frequencies and when, moreover, these signal-waves are to be simultaneously developed, it is obviously necessary that the trains of waves of different frequencies developed in the elevated conductor shall be independent of each other—*i. e.*, it is necessary that the electric vibrations of one frequency impressed upon the elevated conductor shall not be affected by the act of simultaneously impressing vibrations of another frequency upon the conductor. The manner of developing the individual electric vibrations of a particular frequency described in this specification is such as to insure *per se* the required independence of the vibrations when several different frequencies are simultaneously impressed upon the elevated conductor. Several forms of such arrangements of the apparatus will nevertheless be hereinafter fully described in order to add to the completeness of the specification.

When the apparatus at a particular station is attuned to the same periodicity as that of the electromagnetic waves emanating from a particular transmitting-station, then this receiving-station will respond to and be capable of selectively receiving messages from that particular transmitting-station to the exclusion of messages simultaneously or otherwise sent from other transmitting-stations in the neighborhood which generate electromagnetic waves of different periodicities. Moreover, by my invention the operator at the transmitting or receiving station may at will adjust the apparatus at his command in such a way as to place himself in communication with any one of a number of stations in the neighborhood by bringing his apparatus into resonance with the periodicity employed by the station with which intercommunication is desired.

In order that the vertical conductor at the transmitting-station shall generate harmonic electromagnetic waves of but a single frequency, I cause the electric vibrations in the conductor to be of a simple harmonic character, and this in turn I accomplish by producing what are substantially forced electric vibrations in the vertical conductor in lieu of producing natural vibrations in the conductor, as has heretofore been practiced. In order that the electric translating apparatus at the receiving-station shall be operated only by electric waves of a single frequency and by no others, I interpose between the vertical conductor at the receiving-station and the translating devices a resonant circuit or circuits attuned to the particular frequency of the electromagnetic waves which it is desired to have operate the translating devices.

Having thus described, broadly, the nature and object of the invention and the electrical principles upon which it is based, the details of the invention may best be described by having reference to the drawings which accompany and form a part of this specification.

The same letters, so far as may be, represent similar parts in all the figures.

Figures 1 to 4 are diagrams already referred to. Fig. 5 is a diagram illustrating one arrangement of the transmitting-station. Fig. 6 is a diagram illustrating an arrangement of the receiving-station. Fig. 7 is a diagram illustrating another form of the transmitting-station. Fig. 8 is a diagram illustrating another form of the receiving-station. Figs. 9 and 15 are diagrams illustrating a detail of the construction at both transmitting and receiving stations. Figs. 10 and 11 are diagrams illustrative of the connection of the coherer at the receiving-stations. Fig. 12 is a diagram illustrating the connection of a condenser-telephone at the receiving-station. Figs. 13 and 16 are diagrams illustrative of forms of transmitter-stations capable of developing signal-waves of two different frequencies. Figs. 14 and 17 are diagrams illustrative of forms of receiving-stations capable of receiving selectively signal-waves of two different frequencies.

In the drawings, V represents a vertical or virtually vertical conductor grounded by the earth connection E.

M, M', M'', and M''' are induction-coils whose primary and secondary wires are I_1, I'_1, I''_1 and I'''_1 and I_2, I'_2, I''_2, I'''_2, respectively.

L, L', and L'' are auxiliary inductance-coils.

C, C', C'', and C''' are electrical condensers.

K and K_1 are coherers.

B is an electric battery.

a is an alternating-current generator.

k and k_1 are circuit-closing keys.

R and R_1 are telegraphic relays or other suitable electric translating devices.

p and p_1 are automatic circuit-interrupters.

s and s_1 are spark-gaps.

In the organization illustrated in Fig. 5 the generator *a* develops an alternating electromotive force of moderate frequency, which when the key *k* is depressed develops a current in the primary circuit of the transformer M'. The transformer M' is so designed as to transform the electromotive force in the primary circuit to a very high electromotive force in the secondary. As the potential difference at the terminals of the secondary I'_2 rises the charge in the condenser C increases till the potential difference is sufficient to break down the dielectric at the spark-gap *s*. When this occurs, the condenser C discharges through the spark at *s*, the primary I_1, and the inductance-coil L. This discharge is oscillatory in character and of very high frequency, as will be explained hereinafter. The high-frequency current so developed passing through the primary I_1 induces a corresponding high-frequency electromotive force and current in the secondary I_2, and forced electric vibrations result in the vertical conductor V, which are practically of a simple har-

monic character. These simple harmonic vibrations in the conductor V develop electromagnetic waves, which are also practically simple harmonic in character, and these, in turn, on impinging upon the vertical conductor at the receiving-station develop therein corresponding simple harmonic vibrations of like frequency.

In the organization illustrated in Fig. 6 the simple harmonic electromagnetic waves of a given frequency or periodicity impinging upon the vertical conductor V develop therein corresponding electrical vibrations of like frequency. By means of the induction-coil M a vibratory electromotive force corresponding in frequency to the electric vibrations in the conductor V is induced in the secondary circuit I_1 L C C'. If the frequency of this induced electromotive force is that to which the circuit I_1 L C C' is attuned, there will be a maximum potential difference developed at the plates of the condenser C, and this potential will operate the coherer K. When the coherer K operates, the resistance of the circuit B R K is enormously diminished and the battery B develops a current which operates the translating device R. The decoherer (not shown in the drawings) is thereby set in operation, and as soon as the impulse passes the coherer is restored to its sensitive condition. If, however, the frequency of the electromagnetic waves which impinge upon the vertical conductor V of the receiving-station depicted in Fig. 6 is not the same as that to which the circuit I_1 L C C' is attuned, the electromotive force induced in this circuit will be different from that to which the circuit will respond by virtue of resonance, and there will be but a negligible potential difference developed at the plates of the condenser C. Under these circumstance the coherer K will not be operated and the signals will not actuate the translating device R.

When transmitting-stations and a corresponding number of receiving-stations are employed, by adjusting the electromagnetic constants of the circuits at the various stations these circuits may be so proportioned or tuned that the energy of the electromagnetic waves emanating from any given transmitting-station will be selectively received and absorbed at a given receiving-station.

Before proceeding to a description of the operation of the other two forms of transmitting and receiving stations (shown in Figs. 7 and 8) it is to be noted that the condenser C in Fig. 5 discharges through the circuit s I_1 L, and its discharge is practically unaffected by its conductive connection with the circuit through I'_2. The reason for this is that the impedance offered by the circuit through I'_2 is enormously greater than that through s I L. Also the discharge through the circuit s I_1 L is of very great frequency, because the frequency of the oscillations of such discharges of condensers is approximately inversely proportional to the square root of the product of the inductance of the circuit by the capacity of the condenser, and for the purpose of this invention the apparatus is so designed that the product of the capacity of the condenser by the inductance of the circuit is made numerically very small. Moreover, the oscillations in the circuit s I_1 L are approximately simple harmonic in character and are practically unaffected by the inductive association with the vertical wire because of the auxiliary inductance furnished by the coil L, it being capable of demonstration that if by means of the coil L the inductance of the circuit L I_1 s is rendered large compared to the mutual inductance between the circuit and the vertical wire the natural oscillations which will take place in the circuit s I_1 L will be practically unaffected by the inductive association with the vertical wire and will therefore be practically of a simple harmonic character, as in the case of the isolated simple circuit shown in Fig. 1. The principle may for the present purpose be stated thus: that when two simple oscillators, each such as that shown in Fig. 1, are inductively associated with each other, as in Fig. 3, the system is a system of two degrees of freedom, and the natural period of oscillation of each simple circuit is modified by the presence of the other; but if the proportions of the circuits be such that the product of the inductance of the two circuits is large compared to the mutual inductance between the circuits the natural period of oscillation of each of the circuits becomes practically the same as if the circuits were isolated. If, further, the electric equilibrium of the circuit s I_1 L be abruptly disturbed and the circuit be then left without impressed force, the oscillations which are developed in it induce corresponding oscillations in the vertical wire, which oscillations are virtually forced vibrations corresponding in frequency with the natural oscillations developed in the circuit s I_1 L and being practically independent as regards their frequency of the constants of the second circuit in which they are induced.

The mathematical expression for the frequency to which a circuit is resonant when it is isolated from all other circuits—*i. e.*, has but a single degree of freedom—is well known and may be stated as follows:

$$n = \frac{1}{2\pi\sqrt{C_1 L_1}}$$

from which

$$L_1 = \frac{1}{C_1 p^2}$$

where n is the frequency, C_1 is the capacity, L_1 is the inductance, and p is the periodicity which equals $2\pi n$. In the case of a circuit of two degrees of freedom, however, in order to make the component circuits each responsive

to the same frequency as when isolated—in other words, to overcome the modifying effect of the mutual inductance of each circuit upon the other—it is necessary to consider in the case of inductive relation the expression:

$$\frac{1}{C_1 p^2} = L_1 - \frac{M^2_{12}\, p \left(L_2 p - \frac{1}{C_2 p}\right)}{R^2_2 + \left(L_2 p - \frac{1}{C_2 p}\right)^2},$$

where C_1 L_1 are the capacity and inductance of the first circuit C_2 L_2 R_2 are the capacity, inductance, and resistance, respectively, of the second circuit and M_{12} is the mutual inductance of the circuits. From these expressions careful consideration will show that the effective inductance of the first circuit has been modified by its inductive relation with the second circuit, and it is:

$$L'_1 = L_1 - \frac{M^2_{12}\, p \left(L_2 p - \frac{1}{C_2 p}\right)}{R^2_2 + \left(L_2 p - \frac{1}{C_2 p}\right)^2}.$$

Similarly we have to consider the expression:

$$\frac{1}{C_2 p^2} = L_2 - \frac{M^2_{12}\, p \left(L_1 p - \frac{1}{C_1 p}\right)}{R^2_1 + \left(L_1 p - \frac{1}{C_1 p}\right)^2}$$

from which it will be seen that the effective inductance of the second circuit has been modified by its inductive relation with the first circuit and is

$$L'_2 = L_2 - \frac{M^2_{12}\, p \left(L_1 p - \frac{1}{C_1 p}\right)}{R^2_1 + \left(L_1 p - \frac{1}{C_1 p}\right)^2}.$$

These two inductances L'_1 and L'_2 are the apparent inductances which each of these circuits would have if acting as a primary to induce simple harmonic vibrations of frequency n in the other. It is therefore necessary in order to overcome the modifying effect of the mutual inductance on either circuit to add to that circuit an auxiliary inductance-coil of inductance large compared to the term of the form

$$\frac{M^2 p \left(L p - \frac{1}{C p}\right)}{R^2 + \left(L p - \frac{1}{C p}\right)^2},$$

or at least so large that when it is added to the natural inductance of the circuit the sum of their inductances is very large compared to the said term.

It is to be understood that any suitable device may be employed to develop the simple harmonic force impressed upon the vertical wire. It is sufficient to develop in the vertical wire practically simple harmonic vibrations of a fixed and high frequency.

The vertical wire may with advantage be so constructed as to be highly resonant to a particular frequency, and the harmonic vibrations impressed thereon may with advantage be of that frequency. The construction of such a vertical wire is shown and described in other applications of mine now pending.

At the receiving-station shown in Fig. 6 the inductance-coil L is introduced in order to supply auxiliary inductance and to permit of the circuit C C' I_1 L being attuned to a particular frequency practically independently of the constants of the vertical wire.

In both the organizations illustrated in Figs. 5 and 6 the inductance-coils L may be made adjustable and serve as a means whereby the operators may adjust the apparatus to the particular frequency which it is intended to employ.

Passing now to the organizations illustrated in Figs. 7 and 8, it is to be noted that they differ, respectively, from those illustrated in Figs. 5 and 6 in that additional resonant circuits C I'_1 L I_1 are interposed between the vertical conductor and the generating and translating devices, respectively.

In the transmitter arrangements illustrated in Fig. 7 the circuit C I'_1 L I_1 is attuned to the same period as the circuit C' L' I'_1 s and merely tends to weed out and thereby screen the vertical wire from any harmonics which may exist in the current developed in the circuit C' L' I'_1 s. This screening action of an interposed resonance-circuit is due to the well-known property of such circuits by which a resonant circuit favors the development in it of simple harmonic currents of the period to which it is attuned and strongly opposes the development in it of simple harmonic currents of other periodicities. In this organization an ordinary spark-coil, (shown at M'',) equipped in the usual way with an interrupter p and condenser C'', is employed, the current being supplied by the battery B. The operation of this organization is substantially the same as that of the organization shown in Fig. 5, hereinbefore described, except for the screening action of the circuit C I'_1 L I_1 and need not, therefore, be further described. Suffice it to say that when the source of vibratory currents is particularly rich in harmonics any suitable number of resonant circuits each attuned to the desired frequency may be connected inductively in series, as shown in Figs. 9 and 15, and interposed between the generating device and the vertical conductor for the purpose of screening the vertical conductor from the undesirable harmonics.

In the organization illustrated in Fig. 8 the electric resonator C I_2 L I_1, interposed between the vertical conductor and the circuit containing the coherer, is attuned to the same period as the circuit L' C' C'' I'_1 and acts to screen the coherer-circuit from the effect of all currents developed in the vertical conductor save that of the current of the particular period to which the receiving-station is

intended to respond. As in the case of the transmitting-station, any suitable number of resonant circuits, each attuned to the particular period to which the station is desired to respond, may be connected, as shown in Figs. 9 and 15, and interposed between the vertical conductor and the coherer circuit. Such circuits so interposed serve to screen the receiver from the effects of all currents which may be induced in the vertical conductor that are not of the period to which the receiving-station is intended to respond.

No mention has heretofore been made of the function of the condensers shown at C' in Fig. 6 and at C' in Fig. 8, as those condensers are not essential to the tuning of the circuits in which they are placed, but merely serve to exclude the current of the batteries B from the resonant circuits. In order that these condensers may not appreciably affect the tuning of the circuits in which they are included, and thereby lower the resonant rise of potential at the plates of the condensers C and C, (shown in Figs. 6 and 8,) they are so constructed as to have large capacities compared to the capacities of C and C in Figs. 6 and 8, respectively.

In Figs. 6 and 8 the coherers K are shown connected in shunt-circuit to the condensers C and C, respectively; but they may be connected serially in the resonant circuit, as shown in Fig. 10, or they may be connected in shunt-circuit to the coil L and condenser C, as shown in Fig. 11.

Though a coherer has been shown and described in the specification as the means of detecting the presence of oscillations in the receiving resonant circuits, under which circumstances it operates as a telegraphic relay to control a local battery circuit including an electric translating device, any other suitable electroreceptive device may be employed to receive the signal—as, for example, a condenser telephone. When a condenser telephone is employed as a receiver, the receiving resonant circuit may be that illustrated in Fig. 12, in which C is the condenser-telephone and also the capacity by which the circuit L C C' L is attuned.

The apparatus shown in Figs. 13, 14, 15, 16, and 17 illustrates methods of associating the apparatus hereinbefore described, and illustrated in Figs. 5, 6, 7, 8, and 9, when two or more stations are to be associated with a common elevated conductor. The operation of each individual station is the same as that already described in connection with Figs. 5, 6, 7, 8, and 9. For the sake of clearness only two stations are shown associated with the common elevated conductor V in the drawings, but it is obvious that any desired number of stations may be associated with a common elevated conductor in the same manner.

An inspection of the drawings will show that Figs. 13 and 16 illustrate two transmitting-stations of the type shown in Fig. 7 associated with a common elevated conductor, whereas Figs. 14 and 17 illustrate two receiving-stations of the type shown in Fig. 8 associated with a common elevated conductor.

When a plurality of stations are associated with a common elevated conductor, each of the stations is characterized by being tuned to a different frequency from that of any of the other stations so associated. In Figs. 13, 14, 15, 16, and 17 it will be observed that the two different stations associated with a common elevated conductor have therein been differentiated by attaching a subscript to the letters of reference in the case of one of the stations and not to the letters of reference of the other station.

The operation of each of the transmitting-stations in Figs. 13 and 16 is identical with that of the transmitting station illustrated in Fig. 7, and the operation of each of the receiving-stations shown in Figs. 14 and 17 is identical with the operation of the receiving-station illustrated in Fig. 8.

To illustrate, the step-up transformer or spark-coil M'' in Figs. 13 and 16 is equipped with an interrupter p and condenser C''', and the current is supplied by the battery B. When the key k is depressed, a high potential is developed in the secondary of M''. As the potential difference at the terminals of the secondary of M'' rises the condenser C'' is charged till the resulting potential difference at s is sufficient to break down the spark-gap s. When this occurs, the condenser C'' discharges through the spark at s, the primary of M, and the inductance-coil L'. This circuit is attuned to a given high frequency, and the oscillatory current which results is therefore of that frequency. This current induces a similar current in the interposed resonant circuit L' M' C M attuned to the same frequency, which current in turn induces a current of corresponding frequency in the conductor V M E.

Passing now to the operation of the receiving-stations shown in Figs. 14 and 17, it may be remarked that since the operation of each of these stations is identical with the operation of the receiving-station shown in Fig. 8 the energy of the waves of one particular frequency will be absorbed by one of the receiving-stations and the energy of the waves of another particular frequency will be absorbed by the other receiving-station. This selective reception of the energy of waves of a particular frequency is independent of the number of waves of different frequencies which may be simultaneously present.

It is to be here noted that the above-described methods of simultaneously transmitting and receiving space-telegraph messages by a common elevated conductor are not described as the preferred methods, but that any way of associating a plurality of the stations shown in Figs. 5, 6, 7, and 8 with a vertical conductor will result in a system for simultaneously transmitting and receiving space-telegraph signals, owing to the fact that these sta-

tions are in themselves inherently selective and are capable of causing the independent development of vibrations of different frequencies in the elevated conductor and of selectively absorbing the energy of different frequencies, since the branch circuits M M in Figs. 16 and 17 are not in themselves selective and since the elevated conductors in Figs. 13 and 14 contain a number of induction coils in series not essential to the operation of any one of the stations singly.

The branch circuits M M of Fig. 17 are not selective, since they contain but one element of a tuned circuit—viz., the inductance of M and M. Vibratory currents, of whatever frequency they may be, communicated by the vertical wire to these circuits will divide among them in single inverse proportion to their electromagnetic impedances and are not selective except for a slight reaction due to the associated circuits C' M' L' and C'' M'' L''. These reactions, so far from tending to make the branches selective to the frequencies to which their associated circuits are intended to respond, will, in fact, cause them to oppose more strongly currents of these frequencies than those to which the associated circuits are not attuned. Again, it is obvious that the inductance of the coil M in Fig. 13 is merely an additional impedance in the elevated conductor, which, to say the least, cannot assist in the development of vibrations in the elevated conductor impressed by circuit C'_1 M_1 L_1 M_1. The same is obviously true of the coil M_1 in the elevated conductor with reference to the operation of the circuit C' M L'. Now passing to the transmitting station shown at Fig. 16, it is obvious that the vibrations communicated by the circuit C' M L' to the elevated conductor V are subject to a shunt due to the coil M_1 in the other branch of the elevated conductor, and, conversely, the vibrations developed in the elevated conductor by the associated circuit C'_1 M'_1 L'_1 are subject to a shunt due to the coil M in the other branch of the elevated conductor. Finally, the coil M in the elevated conductor in Fig. 14 can at best only present an impedance to the waves intended to be received by the circuit C'_1 M'_1 L'_1, and, conversely, the coil M_1 in the elevated conductor can at best only present an impedance to the vibrations intended to be received by the circuit C' M' L'.

In constructing the various parts of the apparatus shown and described in this specification there is great latitude as to the special forms that may be given them; but it must be remembered that when a circuit is to be tuned and it is desired to gain a high degree of resonance both electrostatic and magnetic hysteresis must be carefully excluded from the resonant circuit. For this reason all iron should be excluded from the coils in the resonant circuits, and solid dielectrics should not ordinarily be employed in the condensers. These injunctions apply to the construction of resonant circuits attuned to very high frequencies, but not with the same force to the construction of resonant circuits to be tuned to low frequencies. Another precaution to be taken in the construction of the apparatus included in the resonant circuits when very high frequency currents are employed is that conductors between which there exists a considerable potential difference during the operation of the apparatus shall be kept as far apart as practical, because of the excessive displacement-currents which tend to flow in the case of high frequency currents. For this reason it will often be found to be convenient to build the coils the form of flat spirals instead of long spirals of several layers, as is the usual construction of coils. Flat spirals with the turns well separated in order to minimize the displacement currents between the turns are, however, by no means the only forms of coils adapted to be used in conjunction with air condensers for the purpose of tuning circuits to high frequencies and may often be neither the best nor most convenient form of coil to employ. Therefore in defining the character of the coils to be employed for this purpose it will be of advantage to first give the general theoretical considerations which lead to a special construction of the coils and to then give a practical guide to the manner of designing the coils for a particular frequency or range of frequencies.

A coil or solenoid as usually constructed consists of many turns of cotton or silk insulated wire wound on an insulating-core, such as a glass or ebonite tube or a wooden spool, the consecutive turns being separated only by the thin insulating coating of the wire. These solenoids, moreover, are in general wound with several layers of wire, the layers also being separated from each other only by the insulating coatings of the wires. Such solenoids are well adapted to be used in conjunction with condensers having solid dielectrics for the purpose of tuning circuits to low frequencies; but neither such coils nor such condensers are available for the purpose of tuning circuits to such high frequencies as are concerned in the present invention. In the case of high frequencies the energy absorbed in the solid dielectric of the condenser due to dielectric hysteresis is excessive and the displacement-currents between the adjacent turns and layers of the coil mask and neutralize the inductance of the coil. Moreover, the solid dielectric forming the core of such coils exerts a deleterious effect, which in some instances is probably partially due to its possessing a small degree of conductivity, but which must in most instances be ascribed to the high specific inductive capacity of the material and to its dielectric hysteresis.

In order to tune a circuit to a predetermined high frequency, so that it shall show a well-defined selectivity for that frequency to the exclusion of other frequencies, even to the exclusion of frequencies differing but slightly from the predetermined frequency, it is nec-

essary not only that the condenser shall be free from dielectric hysteresis, but that the coil shall be so constructed as to behave for that frequency practically like a conductor having a fixed resistance and a fixed inductance, but devoid of capacity. Coils constructed in the usual way do not behave for high frequencies as if they had a fixed resistance and inductance and no capacity, but partake more of the character of conductors having distributed resistance, inductance, and capacity. In fact, they may in some instances behave with high frequencies more like condensers than like conductors having fixed resistance and inductance and no capacity. Since a coil constructed in the usual way behaves for high frequencies as a conductor having distributed resistance, inductance, and capacity, it follows that such a coil will show for high frequencies the same quasi-resonance as is observed with low frequencies in long aerial lines and cables—*i. e.*, that it will *per se* and without the intermediary of a condenser show a slight degree of selectivity for some particular frequency and for certain multiples of that frequency just as a stretched string which has distributed inertia and elasticity will respond to a particular tone called its "fundamental" and to all other tones whose periods are aliquot parts of the periods of that fundamental; but it is not with such quasi-resonance that the present invention is carried into effect, and I wish it understood that I here disclaim any system employing distributed inductance and capacity as a means of tuning the resonant circuits described in this specification.

A general criterion which determines the utility of a coil for tuning a circuit to a particular high frequency is that the potential energy of the displacement-currents in the coil shall be small compared to the kinetic energy of the conduction-current flowing through the coil when the coil is traversed by a current of that frequency.

I have found that for a single-layer coil the following procedure is sufficient for practical purposes. Determine the inductance of the coil by formulæ to be found in the text-books and treatises on electricity and magnetism. This will enable the kinetic energy of the coil to be determined for any particular current and will also permit of the determination of what would be the potential gradient along the coil for the current of the frequency to be employed if the coil were devoid of distributed electrostatic capacity. Next calculate the electrostatic capacity between an end turn and each of the remaining turns of the coil. These capacities, together with the potential gradient found, will enable the potential energy to be determined, and if the ratio of the potential energy to the kinetic energy so found be negligible compared to unity the coil will practically satisfy the requirements hereinbefore mentioned. If the coil does not meet the requirements, the design should be so changed as to increase the separation between the turns or the size of the wire should be diminished or the dimensions of the coil so otherwise altered as to decrease the distributed capacity without proportionately diminishing the inductance. The calculations may be greatly abbreviated and the liability to error greatly reduced if the results of the computations be plotted in curves.

Regarding the effect of a dielectric core in a coil to be used for tuning a circuit to a high frequency, it is sufficient to state that the preferred form of support for such a coil is any skeleton frame which will hold the turns of wire in place without exposing much surface of contact to the wires and affording a minimum of opportunity for the development of displacement-currents within itself.

In this specification I have spoken of elevated conductors, vertically-elevated conductors, and vertical conductors. I wish to be understood as including in the term "elevated" conductors disposed at an angle to the earth's surface as distinguished from horizontal conductors disposed parallel to the earth's surface. By the terms "vertically elevated" and "vertical" I refer to conductors whose disposition with regard to the earth's surface is mainly or wholly at a right angle or vertical thereto, which is the particular form of elevated conductor preferred by me for use in connection with my present improvement.

In this specification I have described the development of free or unguided electromagnetic signal-waves of a given frequency by employing in association with an elevated conductor a circuit such as to produce therein forced simple harmonic electric vibrations of the frequency desired. I have also described a method of receiving or absorbing the energy of free or unguided simple harmonic electromagnetic waves of one frequency to the exclusion of waves of a different frequency by associating with an elevated conductor a circuit made resonant to the frequency of the waves whose energy is to be absorbed. The circuit whereby forced simple harmonic electric vibrations are produced in the elevated conductor I have shown as a circuit containing a condenser and a self-induction coil so proportioned as to make the natural vibrations of a frequency which is the frequency of the vibrations to be forced or impressed in an elevated conductor. The circuit whereby the energy of the electromagnetic waves of one frequency is absorbed to the exclusion of that of waves of another frequency is in like manner a circuit containing a condenser and a self-induction coil so proportioned as to make the circuit resonant to a frequency which is the frequency of the waves the energy of which is to be received. Both of the circuits I have spoken of are tuned circuits, and they may be conveniently distinguished with reference to their respec-

tive functions by denominating the circuit employed in the development of the vibrations as an "oscillating" or "sonorous" circuit and by denominating the circuit employed in the reception or absorption of the vibrations as a "resonant" circuit. I prefer to make this discrimination in nomenclature for the reason that while both the circuits are resonant circuits, yet functionally only that one employed for receiving or absorbing is accurately so described. Except for this distinction in function it is well to note that all oscillating or sonorous circuits are resonant circuits, but only such resonant circuits as have their resistance less than the square root of the ratio of four times their inductance by their capacity are oscillating or sonorous circuits.

Also throughout this specification I have described the electrical oscillations or vibrations and the free or unguided electromagnetic waves or radiations as simple harmonic. It is the object of my present invention to approach as nearly as possible to the perfect simple harmonic wave and such ideal is attained to within such a degree of precision as to preclude any possible interference with the operation of the system by any departure that can exist in the wave from the absolute simple harmonic form. My reason for confining the description of the electrical oscillations or vibrations and the electromagnetic waves or radiations to the simple harmonic type is that in the operation of the system only simple harmonic waves and vibrations are effective in carrying out the object of the invention. If in any similar system of selective space telegraphy there be frequent, even minute, overtones accompanying the simple harmonic signal waves, such overtones will not only not contribute to the useful operation of the system, but may, in fact, become obstacles to such useful and complete operation. It is for this reason that I have taken every precaution to obtain a true or absolute simple harmonic wave form.

Specifically, though it may be possible to employ for the purpose of multiple and selective wireless telegraphy electric vibrations and radiations departing considerably from the simple harmonic type by employing at the receiving end circuits selective to the fundamental of such vibrations and radiations, yet it will only be through the selective reception of that simple harmonic component of the vibrations or radiations which is their fundamental that the system will be operative. The other simple harmonic components of the vibrations or radiations add nothing to the operation of the system. Moreover, if such overtones exist in the waves emanating from a transmitting station their presence will preclude the possibility of placing receiving stations in the immediate neighborhood of such transmitting station for the reception of signal-waves of frequencies corresponding to the frequencies of such overtones.

Whereas in the present specification I have used the term "elevated" conductor to describe the source of radiation of electromagnetic waves developed by forced electric vibrations impressed thereon, yet I deem it proper to point out that this expression should not be confused with the term "conductor" when used in connection with systems wherein that term is employed to denote a wire or other metallically continuous conductor extending from a transmitting to a receiving station. It is of course obvious that in the art to which the present specification relates such a conductor is wholly absent. The vertical metallically continuous source of radiant energy is a structure the location and function of which are confined entirely to the transmitting, or it may be the receiving, end of a system in which the conductor which connects the transmitting and receiving stations is the non-metallic non-conducting—in fact, dielectric—medium, which is commonly called the "ether" and which is by many assumed to be essential to the theory of the propagation of electrical and magnetic force, radiant light, and radiant heat.

Having described my invention, I claim—

1. In a system for developing free or unguided simple harmonic electromagnetic signal waves of a definite frequency, an elevated conductor and means for developing therein forced simple harmonic electric vibrations of corresponding frequency.

2. In a system for receiving the energy of free or unguided simple harmonic electromagnetic signal waves of a definite frequency, to the exclusion of the energy of signal waves of other frequencies, an elevated conductor and a resonant circuit associated with said conductor and attuned to the frequency of the waves, the energy of which is to be received.

3. In a system for independently developing free or unguided simple harmonic electromagnetic signal waves of different frequencies, an elevated conductor and means for independently developing therein forced, simple harmonic, electric vibrations of different and corresponding frequencies.

4. In a system for selectively receiving the energy of free or unguided, simple harmonic, electromagnetic signal waves of different frequencies, each to the exclusion of the rest, an elevated conductor, and resonant circuits associated with said conductor and each attuned to the frequency of a different one of the trains of waves, the energy of which is to be received.

5. In a system for independently developing free or unguided simple harmonic, electromagnetic signal waves of different frequencies, a plurality of elevated conductors corresponding to the number of said different frequencies, and means for impressing upon each

of said conductors forced simple harmonic electric vibrations corresponding to a different one of the said frequencies.

6. In a system for selectively receiving the energy of free or unguided simple harmonic, electromagnetic signal-waves of different frequencies, a plurality of elevated conductors corresponding in number to the number of different frequencies to be received, and resonant circuits each associated with a different elevated conductor, and each attuned to a different one of the said frequencies.

7. In a system for producing free and unguided electromagnetic signal-waves of a definite frequency, an elevated conductor, a source of electrical energy and a group of resonant circuits interposed between said elevated conductor and said source of electrical energy, said circuits being attuned to the frequency of the waves to be developed.

8. In a system for receiving the energy of free or unguided simple harmonic, electromagnetic signal-waves of one frequency to the exclusion of the energy of those of other frequencies, an elevated conductor, an electric translating device, and a group of resonant circuits interposed between said elevated conductor and said electric translating device, said circuits being resonant to the frequency of the waves, the energy of which is to be received.

9. In a system for developing free or unguided simple harmonic, electromagnetic signal-waves, a condenser, means for charging and discharging said condenser through a closed circuit having inductance adapted to produce under such conditions simple harmonic electric vibrations, and means for communicating the vibrations so produced to an open circuit or elevated conductor.

10. In a system for developing free or unguided, simple harmonic, electromagnetic signal-waves, a condenser, means for charging and discharging said condenser through a closed circuit having inductance adapted to produce under such conditions simple harmonic electric vibrations, means for communicating said vibrations to a resonant circuit or group thereof attuned to the frequency of these vibrations and means of communicating the resulting electrical vibrations in said resonant circuit or group thereof to an open circuit or elevated conductor.

11. A circuit resonant to a given high frequency comprising a coil having the amplitude of its potential energy small compared to the amplitude of its kinetic energy when it is supporting a current of said given high frequency, and a condenser adapted to balance by its reactance, the reactance of said coil for said given high frequency.

12. In a circuit resonant to a given high frequency, a coil having the amplitude of its potential energy small compared to the amplitude of its kinetic energy when supporting a current of said given high frequency.

13. In a system for selectively receiving the energy of free or unguided simple harmonic electromagnetic signal-waves of different frequencies, an elevated conductor, and a plurality of resonant circuits associated with said elevated conductor, each resonant to the particular frequency of the electromagnetic waves, the energy of which it is to receive.

14. In a system for selectively receiving the energy of free or unguided simple harmonic, electromagnetic, signal-waves of different frequencies, a plurality of elevated conductors, each associated with a circuit resonant to the particular frequency of the electromagnetic waves, the energy of which it is to receive.

15. In a system for selectively receiving the energy of free or unguided simple harmonic, electromagnetic, signal-waves of different frequencies, a plurality of elevated conductors, each associated with a group of circuits resonant to the particular frequency of the electromagnetic waves the energy of which it is to receive.

16. In a system for selectively receiving the energy of free or unguided simple harmonic, electromagnetic signal-waves of different frequencies, an elevated conductor and a plurality of groups of resonant circuits associated with said elevated conductor, each of said groups of circuits being resonant to the particular frequencies of the electromagnetic waves, the energy of which it is to receive.

17. In a system for receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of a definite frequency to the exclusion of energy of signal-waves of other frequencies, an elevated conductor and a group of resonant circuits associated with said conductor and attuned to the frequency of the waves, the energy of which is to be received.

18. In a system for selectively receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of different frequencies, each to the exclusion of the rest, an elevated conductor and a plurality of resonant circuits associated with said conductor and each attuned to the frequency of a different one of the trains of waves, the energy of which is to be received.

19. In a system for selectively receiving the energy of free or unguided simple harmonic, electromagnetic signal-waves of different frequencies, a plurality of elevated conductors corresponding in number to the number of different frequencies to be received, and groups of resonant circuits each associated with a different elevated conductor, and each attuned to a different one of the said frequencies.

20. In a system for developing free or unguided simple harmonic, electromagnetic signal-waves or radiations, an elevated conductor, associated closed oscillating circuits, means for disturbing the electrical equilibrium of said oscillating circuits, and means for swamping the effect of the mutual inductance between said circuit and the elevated conductor.

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21. In a system for independently developing free or unguided electromagnetic signal-waves or radiations of different frequencies, an elevated conductor, associated closed oscillating circuits each attuned to a different one of the frequencies to be developed, and each of said oscillating circuits having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the other oscillating circuits and between it and the elevated conductor.

22. In a system for receiving the energy of simple harmonic, electromagnetic waves of a given frequency, to the exclusion of like waves of different frequencies, an elevated conductor, a circuit associated with said elevated conductor and made resonant to the frequency of the electromagnetic waves, the energy of which is to be received, by the condenser and an auxiliary inductance-coil whose inductance is sufficient to swamp the effect of the mutual inductance between the associated circuit and the elevated conductor.

23. In a system for receiving the energy of simple harmonic, electromagnetic waves of one frequency, to the exclusion of like waves of different frequencies, an elevated conductor, associated circuits each resonant to the frequency of the electromagnetic waves to be received, and each having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the other associated circuits and between it and the elevated conductor.

24. In a system for developing simple harmonic, electromagnetic signal waves or radiations of a given frequency, a metallically-continuous vertical oscillator and means for impressing thereon simple harmonic, electrical, oscillations of the same frequency.

25. In a system for simultaneously developing simple harmonic, electromagnetic, signal waves of different frequencies, a metallically-continuous vertical oscillator, and means for impressing thereon simple harmonic, electrical oscillations of the same frequencies.

26. In a system for receiving the energy of free or unguided, simple harmonic, electromagnetic waves, an elevated conductor, a circuit associated with said elevated conductor and resonant to the frequency of the electromagnetic waves, and an electric translating device shunted around the terminals of one of the elements of said resonant circuit.

27. In a system for receiving the energy of free or unguided, simple harmonic, electromagnetic waves, an elevated conductor, a group of resonant circuits associated with said resonant conductor, resonant to the frequency of the electromagnetic waves, and an electric translating device shunted around the terminals of that one of said resonant circuits which is farthest removed from the elevated conductor.

28. In a system for receiving the energy of free or unguided, simple harmonic, electromagnetic waves, an elevated conductor and an electric translating device forming one of the elements of a resonant circuit associated with said elevated conductor and resonant to the frequency of the electromagnetic waves.

29. In a system for receiving the energy of simple harmonic, electromagnetic waves of a given frequency, to the exclusion of like waves of different frequencies, an elevated conductor, a circuit associated with said elevated conductor and made resonant to the frequency of the electromagnetic waves, the energy of which is to be received, and means for swamping the effect of the mutual inductance between said circuit and the elevated conductor.

30. In a system for receiving the energy of simple harmonic, electromagnetic waves of one frequency, to the exclusion of like waves of different frequencies, an elevated conductor, associated circuits each resonant to the frequency of the electromagnetic waves to be received, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

31. In a system for receiving the energy of free or unguided, simple harmonic, electromagnetic signal waves of a definite frequency, to the exclusion of the energy of signal-waves of other frequencies, an elevated conductor, a resonant circuit associated with said conductor and attuned to the frequency of the waves, the energy of which is to be received, and means for swamping the effect of the mutual inductance between said circuit and the elevated conductor.

32. In a system for selectively receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of different frequencies, each to the exclusion of the rest, an elevated conductor, resonant circuits associated with said conductor and each attuned to the frequency of a different one of the trains of waves, the energy of which is to be received, and means for swamping the effect of the mutual inductance between said circuit and the elevated conductor.

33. In a system for selectively receiving the energy of free or unguided, simple harmonic electromagnetic, signal-waves of different frequencies, a plurality of elevated conductors corresponding in number to the number of different frequencies to be received, resonant circuits each associated with a different elevated conductor and each attuned to a different one of the said frequencies, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

34. In a system for producing free and unguided, electromagnetic signal-waves of a definite frequency, an elevated conductor, a source of electrical energy, a group of resonant circuits interposed between said elevated conductor and said source of electrical energy, said circuits being attuned to the frequency

of the waves to be developed, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

35. In a system for receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of one frequency, to the exclusion of the energy of those of other frequencies, an elevated conductor, an electric translating device, a group of resonant circuits interposed between said elevated conductor and said electric translating device, said circuits being resonant to the frequency of the waves, the energy of which is to be received, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

36. In a system for developing free or unguided, simple harmonic, electromagnetic signal-waves, a condenser, means for charging and discharging said condenser through a closed circuit having inductance adapted to produce under such conditions simple harmonic, electric vibrations, means for communicating the vibrations so produced to an elevated conductor, and means for swamping the effect of the mutual inductance between said circuit and the elevated conductor.

37. In a system for developing free or unguided, simple harmonic, electromagnetic signal-waves, a condenser, means for charging and discharging said condenser through a closed circuit having inductance adapted to produce under such conditions simple harmonic, electric vibrations, means for communicating said vibrations to a resonant circuit or group thereof attuned to the frequency of these vibrations, means of communicating the resulting electrical vibrations in said resonant circuit or group thereof to an elevated conductor, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

38. In a system for selectively receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of different frequencies, an elevated conductor, a plurality of resonant circuits associated with said elevated conductor, each resonant to the particular frequency of the electromagnetic waves, the energy of which it is to receive, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

39. In a system for selectively receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of different frequencies, a plurality of elevated conductors, each associated with a circuit resonant to the particular frequency of the electromagnetic waves, the energy of which it is to receive, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

40. In a system for selectively receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of different frequencies, a plurality of elevated conductors, each associated with a group of circuits resonant to the particular frequency of the electromagnetic waves the energy of which it is to receive, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

41. In a system for selectively receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of different frequencies, an elevated conductor, a plurality of groups of resonant circuits associated with said elevated conductor, each of said groups of circuits being resonant to the particular frequencies of the electromagnetic waves, the energy of which it is to receive, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

42. In a system for receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of a definite frequency, to the exclusion of energy of signal-waves of other frequencies, an elevated conductor, a group of resonant circuits associated with said conductor attuned to the frequency of the waves, the energy of which is to be received, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

43. In a system for selectively receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of different frequencies, each to the exclusion of the rest, an elevated conductor, a plurality of resonant circuits associated with said conductors and each attuned to the frequency of a different one of the trains of waves, the energy of which is to be received, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

44. In a system for selectively receiving the energy of free or unguided, simple harmonic, electromagnetic signal-waves of different frequencies, a plurality of elevated conductors corresponding in number to the number of different frequencies to be received, groups of resonant circuits each associated with a different elevated conductor, and each attuned to a different one of the said frequencies, and means in each of said circuits for swamping the effect of the mutual inductance between it and the other circuits and between it and the elevated conductor.

JOHN STONE STONE.

In presence of—

ALEX. P. BROWNE,

ELLEN B. TOMLINSON.

2—390

DEFENDANT'S EXHIBIT R-3

3685

DEPARTMENT OF THE INTERIOR,

UNITED STATES PATENT OFFICE.

To all persons to whom these presents shall come, Greeting:

THIS IS TO CERTIFY that the annexed is a true copy from the records of this office of the File Wrapper and Contents, in the matter of the

Letters Patent of

John Stone Stone, Assignor to Louis E. Whicher, Alexander P. Browne, and Brainerd T. Judkins, Trustees,

Number 714,756, Granted December 2, 1902,

for

Improvement in Methods of Selective Electric Signaling.

IN TESTIMONY WHEREOF I have hereunto set my hand and caused the seal of the Patent Office to be affixed, at the City of Washington, this twentieth day of October, in the year of our Lord, one thousand nine hundred and twenty-four and of the Independence of the United States of America the one hundred and forty-ninth.

Wm A Kinnan

Acting Commissioner of Patents.

NUMBER (SERIES OF 1900)
4505

PATENT No. 714,756

Name John Stone Stone
Assor. to Louis E. Whicker, Alexander P. Brown
Edw. T. ~~Damon~~ J. Judkins, Trustees
Brainerd

of Boston
County of
State of Massachusetts
Invention Method of Selective Electric Signaling

ORIGINAL		RENEWED	
Petition Feb 8	1900		190
Affidavit	1900		190
Specification	1900		190
Drawing	1900		190
Model or Specimen none	190		190
First Fee Cash 15 Feb 8	1900		190
Cert.	190		190
App. filed complete Feb 8	1900		190

Examined E. C. Kay Ex. June 20, 1902 | 190
Countersigned A. Babson | 190
Notice of Allowance | 1902 | 190
Final Fee Cash $20 Nov 8 | 1902 | 190
Cert. | 190 | 190

Patented December 2 | 1902
Certificate of Correction December 8 | 1903

Associate Attorney Watson & Watson, Wash. D.C.
Attorney Alex P. Browne, 31 State St., Boston, Mass.

Name | Serial Number
Patent No. | Date of Patent

4505.

3687

Div.

(Serial Number.) 15,00 (Exr's Book.)

4565

Patent No. 711,786

John Stone Stone.

Of Boston

County of

State of Massachusetts

Invention

~~Method of and Apparatus for~~ Selective Electric Signaling.

Parts of Application filed.

Petition Feb. 15, 1900.

Affidavit " "

Specification " " "

Drawing " "

Model

Specimen

First Fee Cash $15. Feb. 15, 1900.

" " Cert.

Appl. filed complete

Examined

Countersigned

Notice of allowance , 190

Final Fee Cash , 190

" " Cert. , 190

Patented Oct. 21 , 1902

Geo. K. Browne
31 State Street
Boston

3252

3688

IN THE UNI[illegible] OFFICE.

Room No. -- SERIAL No. ----

Application of John Stone [illegible],

Patent for Improvement in Methods [illegible] apparatus for Selective Electric Signalling,

[illegible] -------------- allowed -----------

In reply to Office Letter of -------------

[illegible] Street, BOSTON, Feb. 7, 1900.

To the Commissioner of Patents, Washington, D.C.

SIR:

[illegible] petition [illegible] power of attorney, [illegible] of drawings, and check for fif- [illegible] filing the above appli- [illegible].

[illegible]lly,

Alex. P. [illegible],

Attorney.

per T.

8253

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APPLICATION FOR LETTERS PATENT.

PETITION

TO THE COMMISSIONER OF PATENTS:

YOUR PETITIONER

residing

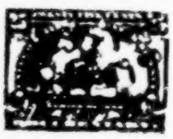
P. O. address, 2 Newbury St. Boston, Mass.

prays that Letters Patent may be granted to him

for the [illegible]

set forth in the annexed specification; and hereby appoint as authorized attorney ALEX. P. BROWNE, of No. 31 State Street, Boston, Mass.,

with full power of substitution and revocation, to prosecute this application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent Office connected therewith.



John Storey Stone

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

Be it known that [illegible]

[illegible]

Follo[illegible]

My invention relates to the art of transmitting intelligence from one station to another by means of electro-magnetic [illegible] the use of wires to guide the waves to their [illegible] and it relates more particularly to the system of [illegible]sion in which the electro-magnetic waves are developed by [illegible]ing electric vibrations in an elevated conductor, [illegible] vertically elevated.

Heretofore in signalling between two stations by means of electro-magnetic waves, when the stations are not connected by a conducting wire, certain disadvantageous limitations have been observed which greatly militated against the commercial value of the methods employed. When the electro-magnetic waves are developed by producing natural or forced electric vibrations in a horizontal conductor, the attenuation of the waves so developed as they travel away from the conductor, is found to be so great as to very seriously limit the distance to which they may be transmitted and effectively received, the chief cause of this observed phenomenon probably being that owing to the horizontal position of the conductor, the plane of polarization of the waves is such as to cause the rapid absorption of the energy of the waves by the conducting surface of the earth or water over which they travel. This difficulty has been overcome by a method of developing the waves which consists in producing natural electric vibrations in a vertically elevated conductor, in which case the plane of polarization of the wave so produced is at quadrature with that of the waves which may be developed by a horizontal wire, and in case of the vertical conductor the attenuation of the waves is observed [illegible]

be very much less than in the case of the horizontal conductor so that these waves may be transmitted to, and effectively received at much greater distances.

A limitation of the commercial utility of this system is however observed which depends upon the fact that it has not heretofore been found possible, so far as I am aware, to direct signals sent out from a transmitter station to the particular receiving station with which it is desired to communicate to the exclusion of other receiving stations equipped with equally or more sensitive receiving apparatus and located within the radius of influence of the sending station.

Electro-magnetic waves have also been developed by producing natural or forced electric oscillations in loops or coils of wire at the transmitting station and also by means of the discharge of electricity between two conducting spheres, cylinders, or cones, but in such cases, the sphere of influence is so limited as to greatly restrict the commercial utility of these methods of developing the signal waves.

In fine, the method of signalling by means of electro-magnetic waves between stations not connected by a conducting wire, in which method the electro-magnetic waves are developed by electric vibrations in an elevated conductor, has great advantages over the other existing or proposed methods for accomplishing this purpose in which the electro-magnetic waves are developed by other means since in the case of the waves developed by the elevated conductor method, the waves may be transmitted to and effectively received at greater distances than by the other systems. But whereas in the systems employing the other methods of generating the waves, the signals de-

veloped may, at least theoretically, be directed to the particular receiving station with which it is desired to communicate to the exclusion of other similar receiving stations in the neighborhood; it has heretofore [illegible] le, so far as I know, to accomplish this purpose in the system employing an elevated [illegible] electromagnetic waves.

The object of this invention is to overcome [illegible] inherent [illegible] limitation to [illegible] waves [illegible] conditions, so [illegible] systems, [illegible] may selectively [illegible] simultaneously [illegible] [illegible] object [illegible] transmitting and receiving stations in such systems [illegible] selectively [illegible] stations.

[illegible]

[illegible] the [illegible] of [illegible] constants.

[illegible] to describe the invention, certain fundamental principles relating to electrical vibrations should be stated, as these principles are involved in the art of signalling by means of what may be called unguided electro-magnetic waves.

If the electrical equilibrium of a [illegible] be [illegible] disturbed and the conductor thereafter be left to itself, electric currents will flow in [illegible] tend to alte-

mately restore the condition of electrical equilibrium. These currents may be either unidirectional or oscillatory in character, depending upon the relation between the principal electro-magnetic constants of the conductor, i.e., upon its electromagnetic and electro-static capacities and its resistance. These phenomena are analogous to the mechanical pehnomena which are observed when the mechanical equilibrium of a system is abruptly disturbed and the system is thereafter left to itself. In the case of a mechanical system, motions result which tend to restore the mechanical equilibrium of the system. These motions may consist either of a unidirectional displacement or of to and fro vibrations of the system or parts of the system, depending upon the relations which subsist between the principal mechanical constantsof the system, i.e., its moments of mass and elasticity and its friction coefficients. In general, the determination of the relations which must subsist in order that an oscillatory restoration of equilibrium shall take plase, either in an electric or in a mechanical system, the determination of the period of these oscillations is very difficult, but in certain simple cases both the determination of the conditions for an oscillatory restoration of equilibrium, and of the period of these oscillations is quite simple.

An example of a simple mechanical system capable of oscillatory restoration of equilibrium is to be found in a tortional pendulum, which consists of a highly [illegible] fixed at one end and supporting at its other extremity a mass called the bob. If a tortional stress be [illegible] wire of this pendulum by turning the bob about the axis of the wire and the bob be then abruptly released, the pendulum [illegible]

in general execute isochronous oscillations about the axis of the suspending wire in the process of restoration of equilibrium. An example of a simple electrical system capable of an oscillatory restoration of equilibrium is to be found in the case of a circuit consisting simply of a condenser and a coil without iron in its core as shown in Fig.1 of the accompanying drawings in which C is a condenser and I is a coil without iron in its core. If a charge of electricity be imparted to the condenser and if its electrodes be then connected to the coil as shown in Fig.1, an isochronous oscillatory current will in general be developed in the circuit in the process of restoration of its electrical equilibrium. Such a simple circuit as that shown in Fig.1 is known as a system with a single degree of freedom, and the electric oscillations which it supports when its equilibrium is abruptly disturbed and it is then left to itself are known as the natural vibrations or oscillations of the system. These vibrations begin with a maximum of amplitude and gradually die away in accordance with what is known as an exponential law, and are what are known as simple harmonic vibrations. They may be represented graphically as in Fig.2, in which A is a curve drawn to rectangular coordinates in which the ordinates represent instantaneous values of current strength and the abscissae represent times.

When two such simple circuits are associated together, inductively as shown in Fig.3, the system so formed is known as a system of two degrees of freedom and in the oscillatory restorations of equilibrium, i.e., in the natural vibrations in such circuits, the currents are in general not simple harmonic in character but in general consist of the superposition of

two simple harmonic currents as shown in Fig.4.

In general, if n simple circuits as shown in Fig.1 be associated together in a system either by conductive or by inductive connections, a system of at least n degrees of freedom results and the natural oscillations of such a system will therefore consist of the superposition of at least n currents. It is moreover a fact that the different simple harmonic components of the oscillations which together constitute the oscillatory restoration of equilibrium of a complex system are in general not the same as those of the separate simple circuits when these circuits are isolated from one another, but the presence of each simple circuit modifies the natural period of each of the other circuits with which it is associated. Thus in a particular case if there be two simple circuits, the first with a natural period of .004 of a second when isolated and the second with a period of .0025 of a second when isolated; these circuits when inductively connected as shown in Fig. 4 have an oscillatory restoration of equilibrium of which the simple harmonic components are .00444 of a second, and .001[illegible] of a second, showing that the inductive association of the circuits together has increased the natural period of the high period circuit, and decreased the natural period of the low period circuit. It is moreover to be remembered that during the restoration of electric equilibrium currents of each of the periods are found in each of the circuits of the connected system.

So far we have considered the natural vibrations of electric systems, i.e., the electric vibrations by means of which the electric equilibrium of circuits is restored after it has been abruptly destroyed and the circuits are left to themselves and we have compared the simple case of such natural electric

[illegible] vibrations with the corresponding natural mechanical vibrations of mechanical systems. We have seen that simple circuits may have simple harmonic natural electric oscillations and that complex circuits will in general, have complex [illegible] oscillations. We have moreover seen that the natural [illegible] oscillations depended upon the electro-magnetic con[illegible] of the circuit in the case of a simple circuit and that [illegible] the periods of oscillation in the case of a complex or [illegible] related circuits depended upon the electro-magnetic [illegible] of each of the interrelated circuits. But besides [illegible] to execute natural vibrations or oscillations, both [illegible] mechanical systems are capable of supporting what [illegible] forced vibrations and in the case of forced vibra[illegible] period of the vibration is independent of the elec[illegible] constants of the circuit on the one hand, and the [illegible] constants of the mechanical system on the other [illegible] and depends only upon the period of the impressed force. [illegible] simple harmonic electro-motive force be impressed [illegible] circuit free from hysteresis, whether it be a simple [illegible] or a complex of simple circuits, the forced vibrations [illegible] resulting from this impressed force will also be [illegible] harmonic, and of the same period as that of the im[illegible]

In the present system of signalling by means of electro[illegible] waves in which a vertical conductor is employed as [illegible] electro-magnetic radiations, the electric oscil[illegible] hereinbefore described as natural vi[illegible] conductor being charged to a high poten[illegible] surrounding earth and permitted to ab[illegible] of an electric spark be-

tween two ball electrodes.

In such a method of developing the electro-magnetic [illegible] waves, the oscillations are necessarily of a complex character, and therefore the resulting electro-magnetic waves are of a complex character and consist of a great variety of superimposed simple harmonic vibrations of different frequencies. The vibrations consist of a simple harmonic vibration of lower period than all the others, known as the fundamental with a great variety of simple harmonics of higher periodicity superimposed thereon. Similarly the vertical conductor at the receiving station is capable of receiving and responding to vibrations of a great variety of frequencies so that the electro-magnetic waves which emanate from one vertical conductor used as a transmitter are capable of exciting vibrations in any other vertical wire as a receiver and for this reason, any transmitting station in a system of this character will operate any receiving-station within its sphere of influence and the messages from the transmitting station will not be selectively received by the particular receiving station with which it is desired to communicate but will interfere with the operation of other receiving stations within its sphere of influence, thereby preventing them from properly responding to the signals of the transmitting stations from which they are intended to receive their signals.

By my invention the vertical conductor of the [illegible] station is made the source of electro-magnetic [illegible] single periodicity, and the translating apparatus [illegible] ceiving station is caused to be selectively responsive to waves of but a single periodicity [illegible]

apparatus corresponds to a tuning fork sending but a single simple musical tone, and the receiving apparatus corresponds to an acoustic resonator capable of absorbing the energy of that single, simple musical tone only.

When the apparatus at a particular station is attuned to the same periodicity as that of the electro-magnetic waves emanating from a particular transmitting station, then this receiving station will respond to and be capable of selectively receiving messages from that particular transmitting station, to the exclusion of messages simultaneously or otherwise sent from other transmitting stations in the neighborhood which generate electro-magnetic waves of different periodicities. Moreover, by my invention the operator at the transmitting or receiving station may at will adjust the apparatus at his command in such a way as to place himself in communication with any one of a number of stations in the neighborhood, by bringing his apparatus into resonance with the periodicity employed [illegible] station with which intercommunication is desired.

In order that the vertical conductor at the transmitting [illegible] shall generate harmonic electro-magnetic waves of but [illegible] frequency, I cause the electric vibrations in the con[illegible] a simple harmonic character and this in turn I [illegible] producing what are substantially forced electric [illegible] the vertical conductor in lieu of producing nat[illegible] the conductor as has heretofore been prac[illegible] the electric ~~transmitting~~ translating apparatus at [illegible] be operated only by electric waves [illegible] and by no others, I interpose between the

vertical conductor at the receiving station and the translat-ing devices, resonant circuit or circuits attuned to the particular fre-quency of the electro-magnetic waves which it is desired to have operate the translating devices.

Having thus described broadly the nature and object of the invention and the electrical principles upon which it is based, the details of the invention may best be described by having reference to the drawings which accompany and form a part of this specification. The same letters, so far as may be, represent similar parts in all the figures.

Figures 1 to 4 are diagrams already referred to.

Fig.5 is a diagram illustrating one arrangement of the transmitting station.

Fig.6 is a diagram illustrating an arrangement of the re-ceiving station.

Fig.7 is a diagram illustrating another form of [illegible] transmitting station.

Fig.8 is a diagram illustrating another form [illegible] ceiving station.

Figs. 9 and 13 are ~~Fig.9 is a~~ diagrams illustrating a detail of [illegible] tion at both transmitting and receiving stations.

Figs.10 and 11 are diagrams illustrative of [illegible] tion of the coherer at receiving stations.

Fig.12 is a diagram illustrating the [illegible] telephone at the receiving station.

(5) Insert C3

In these drawings v represe[illegible] vertical conductor grounded [illegible]

M, M', M'' and M'' are induc[illegible] mary [illegible] are I, I' and I, and I [illegible]

¶ L, L' and L'' are auxiliary inductance coils.

and C'''
¶ C, C' ~~and~~ C'' are electrical condensers.

and K are coherers
¶ K ~~is a coherer~~

¶ B is an electric battery ~~and Plant~~ ~~Pair Plante batteries~~.

¶ g is an alternating current generator

and k are keys
¶ k ~~is a~~ circuit closing ~~key~~.

and R are relays
¶ R ~~is a~~ telegraphic ~~relay~~ or other suitable electric translating ~~device~~. devices

and P are interrupters
¶ P ~~is an~~ automatic circuit ~~interrupter~~.

S are
¶ s ~~is a~~ spark gap

¶ In the organization illustrated in Fig. 5 the generator g develops an alternating electro-motive force of moderate frequency which when the key k is depressed develops a current in the primary circuit of the transformer M'. The transformer M' is so designed as to transform the electro-motive force in the primary circuit to a very high electro-motive force in the secondary. As the potential difference at the terminals of the secondary I_1' rises, the charge in the condenser C increases till the potential difference is sufficient to break down the dielectric at the spark gap s. When this occurs, the condenser C discharges through the spark at s the primary I_1 and the inductance coil L. This discharge is oscillatory in character and of very high frequency as will be explained hereafter. The high frequency current so developed passing through the primary I_1 induces a corresponding high frequency electro-motive force and current in the secondary I_a and forced electric vibrations result in the vertical conductor v, which are practically of a simple harmonic character. These simple harmonic vibrations in the conductor v develop electro-magnetic waves,

which are also practically simple harmonic in character and these in turn on impinging upon the vertical [illegible] at the receiving station develop therein corresponding [illegible] harmonic vibrations of like frequency.

8

In the organization illustrated in Fig. 6, [illegible] monic electro-magnetic waves of a given frequency or periodicity impinging upon the vertical conductor v develop [illegible] corresponding electrical vibrations of like frequency. [illegible] means of the induction coil M, a vibratory electro-motive force corresponding in frequency to the electric vibrations in the conductor v is induced in the secondary circuit I,L,C,C'. If the frequency of this induced electro-motive force is that to which the circuit I,L C C' is attuned, there will be a maximum potential difference developed at the plates of the condenser C, and this potential will operate the coherer K. When the coherer K operates, the resistance of the circuit E R K is enormously diminished and the battery B develops a current which operates the translating device R. The decoherer, not shown in the drawing, is thereby set in operation and as soon as the impulse passes, the coherer is restored to its sensitive condition. If however the frequency of the electro-magnetic waves which impinge upon the vertical conductor v of the receiving station depicted in Fig. 6 is not the same as that to which the circuit I,L C C' is attuned, the electro-motive force induced in this circuit will be different from that to which the circuit will respond by virtue of resonance, and there will be but a negligible potential difference developed at the plates of the condenser C. Under these circumstances the coherer K will not be operated and the signals will not actuate the translating device R.

When transmitting stations and a corresponding number of receiving stations are employed, by adjusting the electro-magnetic constants of the circuits at the various receiving stations, these circuits may be so proportioned or tuned that the energy of the electro-magnetic waves emanating from any given transmitting station will be selectively received and absorbed at a given receiving station.

Before proceeding to a description of the operation of the other two forms of transmitting and receiving stations shown in Figs.7 and 8, it is to be noted that the condenser C in Fig.5 discharges through the circuit s I L, and its discharge is practically unaffected by its conductive connection with the circuit through I'. The reason for this is that the impedance offered by the circuit through I' is enormously greater than that through s I L. Also the discharge through the circuit s I L is of very great frequency because the frequency of the oscillations of such discharges of condensers is approximately inversely proportional to the square root of the product of the inductance of the circuit by the capacity of the condenser and for the purpose of this invention the apparatus is so designed that the product of the capacity of the condenser by the inductance of the circuit is made numerically very small. Moreover the oscillations in the circuit s I L are approximately simple harmonic in character and are practically unaffected by the inductive association with the vertical wire because of the auxiliary inductance furnished by the coil I, it being capable of demonstration that if by means of the coil I, the inductance of the circuit L I s is rendered large compared the mutual inductance between the circuit and the vertical

wire, the natural oscillations which will take place in the circuit s I, L will be practically unaffected by the inductive association with the vertical wire and will therefore be practically of a simple harmonic character as in the case of the isolated simple circuit shown in Fig.1. The principle may, for the present purpose, be stated thus:- That when two simple oscillators, each such as that shown in Fig.1, are inductively associated with each other as in Fig.3, the system is a system of two degrees of freedom, and the natural period of oscillation of each simple circuit is modified by the presence of the other, but if the proportions of the circuits be such that the product of the inductances of the two circuits is large compared to the mutual inductance between the circuits, the natural period of oscillation of each of the circuits becomes practically the same as if the circuits were isolated. If further, the electric equilibrium of the circuit s I, L be abruptly disturbed and the circuit be then left without impressed force, the oscillations which are developed in it induce corresponding oscillations in the vertical wire, which oscillations are virtually forced vibrations, corresponding in frequency with the natural oscillations developed in the circuit s I, L and being practically independent, as regards their frequency, of the constants of the second circuit in which they are induced.

(31) Insert G4

It is to be understood that any suitable device may be employed to develop the simple harmonic force impressed upon the vertical wire. It is sufficient to develop in the vertical wire practically simple harmonic vibrations of a fixed and high frequency.

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G4 Insert G4 5

At the receiving station shown in Fig.6 the inductance coil L is introduced in order to supply auxiliary inductance and to permit of the ~~current~~ circuit C C' I_1 L being attuned to a particular frequency practically independently of the constants of the vertical wire.

In both the organizations illustrated in Figs.5 and 6, the inductance coils L may be made adjustable and serve as a means whereby the operators may adjust the apparatus to the particular frequency which it is intended to employ.

Passing now to the organizations illustrated in Figs.7 and 8, it is to be noted that they differ respectively from those illustrated in Figs.5 and 6 in that additional resonant circuits C I' L I_1 are interposed between the vertical conductor and the generating and translating devices respectively.

In the transmitter arrangements illustrated in Fig.7, the circuit C I' L I_1 is attuned to the same period as the circuit C' L I'_1 s and merely tends to weed out and thereby screen the vertical wire from any harmonics which may exist in the current developed in the circuit C' L' I'_1 s. This screening action of an interposed resonant circuit is due to the well known property of such circuits by which a resonant circuit favors the development in it of simple harmonic currents of the period to which it is attuned and strongly opposes the development in it of simple harmonic currents of other periodicities. In this organization an ordinary spark coil, shown at M", equipped in the usual way with an interrupter p and condenser C" is employed, the current being supplied by the battery B. The operation of this organization is substantially the same as that of the organization shown in Fig.5, hereinbefore described, except for the screening action

of the circuit C I'_a L I_1 and need not therefore be further described. Suffice it to say that when the source of vibratory currents is particularly rich in harmonics any suitable number of resonant circuits, each attuned to the desired frequency may be connected inductively in series, as shown in Figs. 9 and 10 ~~Fig. 4~~ and interposed between the generating device and the vertical conductor for the purpose of screening the vertical conductor from the undesirable harmonics.

In the organization illustrated in Fig. 8, the electric resonator C I'_a L I, interposed between the vertical conductor and the circuit containing the coherer is attuned to the same period as the circuit L' C' C" I', and acts to screen the coherer circuit from the effect of all currents developed in the vertical conductor save that of the current of the particular period to which the receiving station is intended to respond. As in the case of the transmitting station, any suitable number of resonant circuits, each attuned to the particular period to which the station is desired to respond may be connected as shown in Figs 9 and 10 ~~Fig. 4~~ and interposed between the vertical conductor and the coherer circuit. Such circuits so interposed serve to screen the receiver from the effect of all currents which may be induced in the vertical conductor that are not of the period to which the receiving station is intended to respond.

No mention has heretofore been made of the function of the condensers shown at C' in Fig. 6 and at C" in Fig. 8, as those condensers are not essential to the tuning of the circuits in which they are placed, but merely serve to exclude the current of the batteries B from the resonant circuits. In or-

der that these condensers may not appreciably affect the tuning of the circuits in which they are included and thereby lower the resonant rise of potential at the plates of the condensers C and C', shown in Figs. 6 and 8, they are so constructed as to have large capacities compared to the capacities of C and C' in Figs. 6 and 8 respectively.

¶ In Figs. 6 and 8, the coherers K are shown connected in shunt circuit to the condensers C and C' respectively, but they may be connected serially in the resonant circuit as shown in Fig. 10, or they may be connected in shunt circuit to the coil L and condenser C' as shown in Fig. 11.

¶ Though a coherer has been shown and described in the specification as the means of detecting the presence of oscillations in the receiving resonant circuits, under which circumstances it operates as a telegraphic relay to control a local battery circuit including an electric translating device, any other suitable electro-receptive device may be employed to receive the signal, as for example, a condenser telephone. When a condenser telephone is employed as a receiver, the receiving resonant circuit may be that illustrated in Fig. 12, in which C is the condenser telephone and also the capacity by which the circuit L C C' I, is attuned.

Cancelled part

~~In Fig. 12 R' is a coil of very great impedence employed to prevent the passage of the electrical oscillations from the resonant circuit L C C' I into the battery circuit and the consequent disturbance of the resonance. The battery B should be of very high potential and it serves to maintain a permanent charge in the condenser telephone C. Such a charge greatly enhances the sensitiveness of the telephone and causes the attraction between its plates to vary more nearly in propor-~~

~~tion to the variations of electro-motive force at its terminals. As it is inconvenient to attain very high potentials by means of primary galvanic batteries, it will be found convenient in practice to employ either a Plante battery of very small capacity but of a large number of cells connected in series or else a condenser charged from time to time to a high potential.~~

11 In constructing the various parts of the apparatus shown and described in this specification there is great latitude as to the special forms that may be given them, but it must be remembered that when a circuit is to be tuned and it is desired to gain a high degree of resonance both electro-static and magnetic hysteresis must be carefully excluded from the resonant circuit. For this reason, all iron should be excluded from the coils in the resonant circuits and solid dielectrics should not ordinarily be employed in the condensers. These injunctions apply to the construction of resonant circuits attuned to very high frequencies, but not with the same force to the construction of resonant circuits to be tuned to low frequencies. Another precaution to be taken in the construction of the apparatus included in the resonant circuits when very high frequency currents are employed is that conductors, between which there exists a considerable potential difference during the operation of the apparatus shall, be kept as far apart as practical, because of the excessive displacement currents which tend to flow in the case of high frequency currents. For this reason it will often be found to be convenient to build the coils in the form of flat spirals instead of long spirals of several layers as is the usual construction of coils.

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In this specification I have spoken of elevated conductors, vertically elevated conductors, and vertical conductors. I wish to be understood as including in the term "elevated", conductors disposed at an angle to the earth's surface as distinguished from horizontal conductors, disposed parallel to the earth's surface. By the terms "vertically elevated" and "vertical", I refer to conductors whose disposition with regard to the earth's surface is mainly or wholly at a right angle or vertical thereto, which is the particular form of elevated conductor preferred by me for use in connection with my present improvement.

Having described my invention, I claim:

1. The method of developing free or unguided simple harmonic electro-magnetic waves of a definite periodicity, which consists in producing ~~fixed~~ forced simple harmonic electric vibrations of the same periodicity in an elevated conductor.

2. The method of absorbing the energy of free or unguided simple harmonic electro-magnetic waves of one periodicity to the exclusion of the energy of free or unguided electro-magnetic waves of different periodicity which consists in associating with an elevated conductor a resonant circuit or a group thereof attuned to the same period as that of the waves the energy of which is to be absorbed.

3. The method of distributing the energy of free or unguided electro-magnetic waves which consists in independently developing forced simple harmonic electric vibrations of different periodicities in elevated conductors and ~~conveying~~ receiving the several energies of the resulting electro-magnetic waves at a distance, each selectively, ~~to~~ in a separate electric translating device.

4. The method of distributing the energy of free or unguided electro-mag-

netic waves which consists in independently developing a number of forced simple harmonic electric vibrations of different periodicities [illegible] elevated conductors and ~~emitting~~ [illegible] the several groups of [illegible] electro-magnetic waves, each selectively [illegible] resonant circuit or group thereof attuned to the said [illegible] waves, the energy of which is to be absorbed therein.

8. A system of utilizing the energy of electro-magnetic waves, comprising an elevated conductor, means of independently developing therein forced, simple, harmonic electric vibrations of a definite periodicity, a resonant circuit or group of circuits, associated with a second elevated conductor attuned to the said definite periodicity, and an electric translating device [illegible].

[illegible]. A system [illegible] the [illegible] of energy of electro-magnetic waves, comprising elevated conductors, means of independently developing therein forced simple harmonic electric vibrations of different definite periodicities, and a number of resonant [illegible] one elevated [illegible] said periodicities, and an electric translating device [illegible] thereof.

[illegible]. A system for developing simple harmonic electro-magnetic waves of a definite periodicity, comprising an elevated conductor, a generator of vibratory electric currents, and a [illegible] resonant circuits, connected inductively in series and interposed between the said conductor and the generator.

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9. A system of absorbing the energy of simple, harmonic electro-magnetic waves, of a definite periodicity, comprising an elevated conductor, an electric translating device, and a group of resonant circuits interposed between the said conductor and the translating device, said circuits being connected inductively in series and attuned to the period of said waves.

7 8 9 8 10 10 16 6 20 8 8 9 7 9 21 9 10 11

12 22 5 5 8 11 12 8 23 10 11 11 14 24 10 11 25 12 9 11 10

In testimony whereof I have hereunto subscribed my hand this 6th day of February, 1900.

Witnesses:

E. D. Chadwick.

Alex P. Browne.

John Stone Stone.

OATH.

State of Massachusetts, County of Suffolk, ss.

John Stone Stone,

the above named petitioner, being duly sworn, deposes and says that he is a citizen of the United States and resident of Boston, in the County of Suffolk and State of Massachusetts, and that he verily believes himself to be the original, first and sole inventor of the Improvements in Methods of and Apparatus for Selective Electric Signalling, described and claimed in the foregoing specification; that he does not know and does not believe the same was ever known or used before his invention thereof, or patented or described in any printed publication in any country, that no application for patent thereon has been filed in any foreign country by him or his legal representatives or assigns; that said improvement has not to his knowledge and belief been in use or on sale in the United States nor described in any printed publication or patented in this or any foreign country for more than two years prior to the date of this application, and he does not know and does not believe that the same was ever known or used prior to his invention thereof.

John Stone Stone.

Subscribed and sworn to before me this 6th day of February, A.D. 1900.

Everett D. Chadwick

Notary Public.

3712

2-248.

4

Room No. 21

All communications should be addressed to "The Commissioner of Patents, Washington, D. C."

All communications respecting this application should give the serial number, date of filing, and title of invention.

DEPARTMENT OF THE INTERIOR,

UNITED STATES PATENT OFFICE,

375

WASHINGTON, D. C., March 10, 1900.

John Shane Stone,

Care, Alexander P. Browne,

31 State St.,

Boston, Mass.

U. S. PATENT OFFICE
MAR 10 1900

Please find below a communication from the **EXAMINER** *in charge of your application.*
filed Feb. 6, 1900. Ser. No. 4505, for Method of and Apparatus for Selective Electric Signaling.

C. H. Duell
Commissioner of Patents.

There appear in this case four claims for methods and four claims for systems, there being no claim 5 in the case. The applicant is not allowed claims on separate and independent inventions, as set out in Rule 41 of the amended Rules of Practice of July 18, 1899. The applicant will elect which claims he will prosecute in this application, when action on the merits will be had.

For the state of the art see the following patents:

Pupin, 540,515, June 2, 1895,
540,318, " " ",
Telegraphy, Telegraphs, Multiplex,

Walker, 350,239, Oct. 5, 1886,
Ellison, 465,971, Dec. 29, 1891,
Fitzee, 550,510, Nov. 26, 1895,
Lodge, 609,154, Aug. 16, 1898,
Marconi, 627,650. June 27, 1899,
British
Lodge, 29,069 and 29,505 of 1897.
Thompson, 528 of 1898,

Telegraphy,
Telegraphs,
Circuits and Systems.

Fred O. Fish

RULE 71. In every amendment the exact word or words to be stricken out or inserted in the application must be specified and the precise point indicated where the erasure or insertion is to be made. All such amendments must be on sheets of paper separate from the papers previously filed, and written on but one side of the paper.

Asst. in Chg. Div. 14

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IN THE UNITED STATES PATENT OFFICE. 3713 2

Room No. 51,

SERIAL NO. [illegible]

Application of John Stone Stone,

for Patent for Improvement in Method of and Apparatus for Selective Electric Signaling,

filed February [illegible], 1900, allowed ---------

In reply to Office Letter of March 10, 1900.

31 State
~~92~~ ~~Water~~ Street, BOSTON, January [illegible], 1901

To the Commissioner of Patents, Washington, D.C.,

SIR:

Pursuant to the requirement of the Examiner the present case is amended by cancelling claims [illegible] and [illegible], as the same form the subject matter of another application sent herewith; also by amending the title of the invention as set forth in the petition and at page 1, line 4 of the specification, by erasing the words "and apparatus for."

Also by erasing from the specification the paragraph beginning at line [illegible], page 1[illegible].

Amend Fig. 1[illegible] of the drawing by erasing the battery B, impedance coil R', and the connections between the same and the resonant circuit L, C, C', L. The portions of the specification and drawings desired to be erased by this amendment were introduced by inadvertence.

Respectfully,

Alex. P. Browne,
atty for appl't

3278 6

2—246.

#3

Room No. 21. 41
(A communications should be addressed to "The Commissioner of Patents, Washington, D. C."

All communications respecting this application should give the serial number, date of filing, and title of invention.

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DEPARTMENT OF THE INTERIOR.

UNITED STATES PATENT OFFICE,

WASHINGTON, D. C. Feb. 12, 1901.

John Stone Stone,

Care, Alexander P. Browne,

31 State St.,

Boston, Mass.

Please find below a communication from the **EXAMINER** *in charge of your application* filed Feb. 3, 1900, Ser. No. 4505, for Method of and Apparatus for Selective Electric Signaling.

C. H. Duell
Commissioner of Patents.

This application has been considered in connection with the amendment of Jan. 23, 1901.

It is thought that applicant intended to refer to figure 3 instead of figure 2 in line 18 of page 7 of his specification.

Claim 1 covers a method for developing simple harmonic electromagnetic waves of a definite periodicity by setting up simple harmonic electric vibrations of the same periodicity of an elevated conductor. The nature or disposition of the conductor in which such electric vibrations are set up in no way effect the method <u>per se</u>. The claim is accordingly rejected upon the patent to Pupin, 640,515, Jan. 2, 1900, Telegraphy, Multiplex.

Claim 2 is rejected upon the patent to Marconi, 627,650, June 27, 1899, Telegraphy, ~~Circuits and Systems, particular reference~~

being had to figure 1.

Claims 3 and 4 are not understood for the reason that it is not clear whether one or several conductors are implied, that is, whether the independent frequencies are impressed upon one or different conductors. However this may be claims 3 and 4 are deemed to be met in the patent to Pupin, 640,516, cited above, and for the reasons stated in connection with claim 1. Attention is also called to the system found in the British patent to Lodge, 29,505 of 1897, of record.

G. C. Dean

Examiner. Div. 16.

300

(9 (9 3716 4

In the United States Patent Office.

Room No. 21, Serial No. 4505,

Application of John Stone Stone,

For Patent for Improvement in Method of and Apparatus for Selective Electric Signaling,

Filed February 6, 1900,

In reply to Office letter of February 1[illegible], 1901.

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31 State street, Boston,

March 23, 1901.

To the Commissioner of Patents,

Washington, D.C.

Sir,

Amend the title by striking out the words "and Apparatus for."

Amend the specification by striking out "2" in line 18 of page 7 and replacing it by "[illegible]".

Amend claim 1 by inserting the words "free or unguided" in line 13, page 20, after the word "developing."

Amend claim 2 by inserting the words "free or unguided" in line 17, page 20, after the words "energy of" and by inserting the words "free or unguided" in line 19, page 20, after the words "energy of."

Amend claim 3 by inserting the words "free or unguided" at line 23, page 20, after the words "energy of." Also by erasing the word "conductors" at line 26, same page, and substituting the word "conductor," also in the same line by inserting the word "an" after the word "in", and by inserting at line 27,

same page, the word "a" after the word "to."

Amend claim 4 by inserting the words "free or unguided" in line 28, page 20, after the words "energy of"; also by erasing the word "conductors" and substituting the word "conductor" at line 8, page 21. Also in the same line by inserting the word "an" after the word "in."

Add two claims 5 and 6 respectively as follows:

"5. The method of distributing the energy of free or unguided electro-magnetic waves which consists in developing forced simple harmonic electric vibrations of different periodicities, each in a different elevated conductor, and ~~conveying~~ selecting the several energies of the resulting electro-magnetic waves, at a distance, each selectively, ~~to~~ in a separate electric translating device.

"6. The method of distributing the energy of free or unguided electro-magnetic waves which consists in developing a number of forced simple harmonic electric vibrations of different frequencies, each in a different elevated conductor, and ~~conveying~~ selecting the several energies of the resulting electro-magnetic waves, at a distance, each selectively, ~~to~~ in a separate resonant circuit, or group thereof, attuned to the same period as that of the waves, the energy of which is to be absorbed therein."

Argument upon the pertinency of the Pupin reference is made for convenience in a separate paper filed herewith.

Respectfully,

Alex P. Browne

Att'y for appel.

4505-30

3718

In the United States Patent Office.

Room No.81, Serial No.4505,

Application of John Stone Stone,

For Patent for Improvement in Method of and Apparatus for Selective Electric Signaling,

Filed February 8,1900,

In reply to Office letter of February 12,1901.

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81 State street,Boston,

March 28,1901.

To the Commissioner of Patents,

Washington,D.C.

Sir,

A r g u m e n t .

Applicant does not understand that the Examiner in rejecting claim 1 of the application upon Pupin's patent No. 640,516 contends that there is no novelty in using in a system of space telegraphy,free or unguided simple harmonic electro-magnetic waves which are developed by producing forced simple harmonic electric vibrations in elevated conductors. He understands that claim 1 is rejected because it is by the Examiner construed to be in terms broad enough to cover a method of developing guided simple harmonic electro-magnetic waves which are developed by producing forced simple harmonic waves in an elevated horizontal conductor or main line,since this is the nature of the disclosure contained in the patent to Pupin referred to by the Examiner.

Such a construction of claim 1 is deemed by the applicant to be too broad since the claim must be construed with refer-

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ence to the specification of which it forms a part, in which the meaning attached by the applicant to the term 'elevated conductor' is explicitly stated (see lines 1 to 11 inclusive, p.20 of the application.) The paragraph in the specification above referred to forbids the interpretation of the term 'elevated conductor' in claim 1 as meaning an elevated horizontal conductor or main line, and it also by virtue of the known physical laws governing the phenomena involved, precludes the interpretation of the term 'simple harmonic electro-magnetic waves' in the claim as including guided simple harmonic electro-magnetic waves.

Electro-magnetic waves emanating from an elevated conductor, if the term elevated conductor be used in the sense in which the applicant has employed it in his specification, are free or unguided except in so far as the earth or water over which they travel may be considered to exert a guiding influence.

Applicant therefore contends that the claim 1 in its original form is not susceptible of a construction which would make it broad enough to include the invention [illegible] claimed in the United States patent to Squier [illegible], 19[illegible], [illegible] 1[illegible],19[illegible].

Nevertheless the applicant for the sake of clearness has amended claim 1 in [illegible] manner as to leave no doubt [illegible] electro-magnetic waves therein referred to are of the unguided type.

Respectfully,

[illegible]

Alex P. Browne
atty for appl't

91.

DEPARTMENT OF THE INTERIOR

UNITED STATES PATENT OFFICE,

WASHINGTON D. C. April 10,1901.

John Stone Stone,

Care, Alex. P. Browne,

31 State St.,

Boston, Mass.

Please find below a communication from the **EXAMINER** *in charge of your application*

filed Feb.8, 1900, Ser. No. 4,505, for Method of and Apparatus for Selective Electric Signaling.

F. I. Allen

Fig. 1a of the drawings will be changed as requested by the applicant, on the filing of proper prints.

Claim 1 is again rejected upon the patent to Pupin, of record. So far as the method of developing the waves is concerned, it is immaterial whether they be guided or free and unguided, and the fact that they are to be used in the wireless system is immaterial. Attention is called to the statement of invention in the Pupin patent.

Claim 2 is again rejected upon the patent to Marconi 627,650 of record. Claims 3 and 4 are each rejected upon Swiss patent to Braun, 18,577, taken in view of Pupin of record.

The application of the Pupin method of developing simple harmonic waves as applied to the Braun system is not patentable.

#4,505.

Claims 3 and 4 are drawn to separate species of inventions as described in claims 5 and 6, and in the drawings does not appear a sufficient showing of a proper basis for any of the claims 3, 4, 5 and 6.

Said claims 5 and 6 amount simply to aggregations. There is no patentable cooperation between independent telegraphic systems which operate with a definite periodicity for its waves.

Examiner, Div. 16.

3722

IN THE UNITED STATES PATENT OFFICE.

To the Commissioner of Patents.

Sir:

In the matter of the application of

John Stone Stone

for Letters Patent for an improvement in Method of and Apparatus for Selective Electric Signaling

Serial No. 4505, filed Feb. 8, 1900

please recognize the firm of WATSON & WATSON, (consisting of James A. Watson, Robert Watson and John Watson, Jr.,) of Washington, D. C., and Baltimore, Md. as my associates.

Respectfully,

Alex P. Browne
atty for applt

3723

IN THE UNITED STATES PATENT OFFICE.

Room No.91. Serial No.4505.

Application of John Stone Stone,

For Patent for Improvement in ~~Apparatus for~~ Method of Selective Electric Signaling.

Filed ~~January 23,1901~~ Feb 8 1900

In reply to Office letter of April 16,1901.

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31 State street, Boston.

April 8,1902.

To the Commissioner of Patents,

Washington,D.C.

Sir:

The case is amended as follows:

Insert in the specification, after the paragraph ending page 4, line 28:

"Thus the frequency impressed upon the elevated conductor may or may not be the same as the natural period or fundamental of such conductor, but as will be hereinafter explained, an elevated conductor that is aperiodic may be employed, and is best adapted for use when the apparatus is to be used successively for different frequencies, and such aperiodic elevated conductor is likewise the preferred form of elevated conductor when two or more frequencies are to be simultaneously impressed upon or received by a single elevated conductor.

"But forced simple harmonic electric vibrations of different periodicities may each be separately impressed upon a different elevated conductor and the several energies of the resulting electromagnetic waves may be selectibly conveyed each to a separate [illegible]

After the paragraph ending page 10, line 4, insert:

"When, however, the elevated conductor is aperiodic it is [illegible] receptive of [illegible] frequencies, and accordingly

a single aperiodic elevated conductor may be associated with a plurality of [illegible] circuits each attuned to a different frequency [illegible] the manner now well known in the art of Multiple Telegraphy [illegible] conductors.

6 [illegible] Where a single elevated conductor is to be made a source of [illegible] plurality of signal waves of different frequencies, and when [illegible], these signal waves are to be simultaneously developed, it [illegible] necessary that the trains of waves of different fre- [illegible] the elevated conductor shall be [illegible] it is necessary that the electric vibrations [illegible] upon the elevated conductor shall not [illegible] simultaneously impressing vibrations [illegible] The manner of developing the [illegible] in this [illegible] different frequencies [illegible] are simultaneously impressed upon the elevated conductor [illegible] preferred forms of such arrangement upon the apparatus will hereinafter [illegible] described in order to add to the completeness of the specification.

Page 11, line 26, erase the word "transmitting" and substitute the word "translating."

Page 11, line 25, insert

"Figs. 15 and 16 are diagrams illustrative of forms of transmitting [illegible] capable of developing signal waves of two different [illegible]

[illegible] and 18 are diagrams illustrative of forms of receiving stations capable of receiving selectively signal waves of two different frequencies."

Page 12, line 2, erase the word "and"; introduce after "C''" the words "and C'''".

Page 12, line 3, erase all after "K" and substitute "and K are coherers."

~~Page 12, line 5, insert [illegible] "battery" [illegible] "and F and B are Planté batteries".~~

PASSED

Page 12, line 6, erase "[illegible]" and substitute [illegible] [illegible] "keying" and substitute "keys."

Page 12, line 7, erase "[illegible]" [illegible] erase "relay" and substitute "relays."

Page 12, line 8, erase "device" and substitute [illegible].

Page 12, line 9, [illegible] erase "interrupter" and substitute [illegible].

Page 12, line 10, [illegible] erase "gap" and substitute [illegible].

At the end of page 12 insert [illegible]

"The terminal wire may with advantage be so constructed as to be highly resonant to [illegible] [illegible] [illegible] [illegible] impressed thereon may [illegible] [illegible] [illegible]. The construction of such a vertical wire is [illegible] [illegible] [illegible] other applications of mine now pending."

The following amendment and [illegible] sheet of drawings to be added by amendment are presented in reference to the [illegible] contained in the Office letter of April 16, 1902, to the effect that there is not sufficient showing in the drawings to form a proper basis for the claims 3, 4, 5 and 6.

The amendment applicant deems to meet the requirements of the Office so far as they relate to claims 3 and 4. As regards the bearing of the Office action in connection with claims 5 and 6, applicant respectfully submits that the drawings marked Figs. 5 to 8, inclusive, are sufficient [illegible] for these claims, since if he were to show in his drawings a system comprising more [illegible] transmitting station and more th[illegible] receiving station, each associated with a separate elevated [illegible], it [illegible] result merely in reduplicating Figs. 5, 6, 7 and 8. This is not [illegible] [illegible] that the several transmitting stations would be identical in construction

and the various receiving stations identical in construction, but because the difference in frequency employed at these stations is not susceptible of being readily shown in the diagrams, or what amounts to the same thing the differences in the inductances of the coils and the capacities of the condensers are not readily [illegible] diagrams of the type used.

[illegible] cannot agree with the Examiner that there is no [illegible] feature in the organization covered by claims 5 and 6. It [illegible] sufficient to note that ever since the art of wireless [illegible] been practised, the great need for commercial purposes [illegible] system as is sought to be covered in claims 5 and 6 has [illegible] fully recognized. Ever since the art of wireless or space telegraphy has existed, the problem, a solution of which is claimed in claims 5 and 6, has been one of vital importance and the principal commercial value of wireless telegraphy has depended upon its practical solution. Applicant contends that he who solves this problem in a thoroughly practical manner has added more to the commercial value of wireless telegraphy than any one else and is entitled to the protection sought to be secured in claims 5 and 6.

Regarding the amendment in question, applicant farther submits that owing to the fact that his transmitting and receiving stations illustrated in Figs. 5, 6, 7 and 8, are inherently selective by virtue of the auxilliary coils L, L', L'', etc., and that a plurality of such stations can therefore be associated in any desired way with a common vertical wire to form the system sought to be covered by claims 5 and 6, he did not at first consider it necessary to include drawings and a detail description of the organization sought to be covered in these claims. Applicant, however, now concurs with the Examiner, and feels that the present amendment to the specification and the added sheets of drawings increase the completeness with which the invention as a whole is set forth.

The amendment which has been referred to above is as follows:
Page 17, after line 24, insert:

"The apparatus shown in Figs. 13,14,15, ~~and~~ 16 and 17 illustrate methods of associating the apparatus hereinbefore described, and illustrated in Figs. 5,6,7, ~~and~~ 8, and 9 when two or more stations are to be associated with a common elevated conductor. The operation of each individual station is the same as that already described in connection with Figs. 5,6,7, ~~and~~ 8, and 9. For the sake of clearness only two stations are shown associated with the common elevated conductor V in the drawings, but it is obvious that any desired number of stations may be associated with a common elevated conductor in the same manner.

"An inspection of the drawings will show that Figs. 13 and ~~15~~ 16 illustrate two transmitting stations of the type shown in Fig. 7 associated with a common elevated conductor, whereas Figs. 14 and ~~16~~ 17 illustrate two receiving stations of the type shown in Fig. 8 associated with a common elevated conductor.

"When a plurality of stations are associated with a common elevated conductor, each of the stations is characterized by being tuned to a different frequency from that of any of the other stations so associated. In Figs. 13,14,15, ~~and~~ 16, and 17 it will be observed that the two different stations associated with a common elevated conductor have therein been differentiated by attaching a subscript to the letters of reference in the case of one of the stations and not to the letters of reference of the other station.

"The operation of each of the transmitting stations in Figs. 13 and ~~15~~ 16 is identical with that of the transmitting station illustrated in Fig. 7, and the operation of each of the receiving stations shown in Figs. 14 and ~~16~~ 17 is identical with the operation of the receiving station illustrated in Fig. 8.

"To illustrate.- The step up transformer or spark coil M'' in Figs. 13 and ~~15~~ 16, is equipped with an interrupter p and condenser C''', and the current is supplied by the battery B. When the key k is depressed, a high potential is developed in the secondary of M''. As the potential difference at the terminals of the secondary of

M' rises, the condenser C'' is charged till the resulting potential difference at a is sufficient to break down the spark gap a. When this occurs, the condenser C'' discharges through the spark gap a, the primary of M', and the inductance coil L''. This circuit is attuned to a given high frequency and the oscillatory current which results is therefore of that frequency. This current induces a similar current in the interposed resonant circuit L', M', C', M attuned to the same frequency, which current in turn induces a current of corresponding frequency in the conductor V L M E. The branch L M C is attuned to the given high frequency of the oscillation developed in the circuits L'' a C'' M' and L' M' C' M while the branch L C M is attuned to the frequency of the oscillations similarly developed in the circuits L'' a C'' M' and L' M' C' M. Since these two frequencies are different as hereinbefore specified, the energy of the oscillations developed in the one branch will not be materially absorbed in the other. In this way two sets of forced oscillations of different frequencies may be developed in the elevated conductor V without mutual interference.

Cancelled

¶ Passing now to the operation of the receiving stations shown in Figs. 14 and ~~16~~ 17, it may be remarked that since the operation of each of these stations is identical with the operation of the receiving station shown in Fig. 8, ~~it only remains to show that~~ the energy of the waves of one particular frequency will be absorbed by ~~communicated only to~~ one of the receiving stations and ~~that~~ the energy of the waves of another particular frequency will be absorbed by ~~communicated only to~~ the other receiving station.

In both Fig. 14 and Fig. 16 the branch circuits L M C and L M C are attuned each respectively to the same particular frequencies as the circuits M L' M' C' M' L'' C'' P and M L' M' C' M' L'' C'' P. When therefore simple harmonic waves of one of these particular frequencies impinge upon the vertical wire V, the energy of these waves is received in that particular branch circuit which is attuned to the frequency of the waves and is practically excluded from the other branch. The energy so received is communicated to the resonant circuits associated with this branch and affects the

Cancelled

~~receiving translating device in the usual manner. This selective reception of the energy of waves of a particular frequency is independent of the number of waves of different frequencies which may be simultaneously present.~~

~~"It is to be here noted that the above described methods of simultaneously transmitting and receiving space telegraph messages by a common elevated conductor are~~ not described as the ~~the preferred methods but that any way of associating a plurality of the stations shown in Figs. 5,6,7 and 8 with a vertical conductor will result in a system for simultaneously transmitting and receiving space telegraph signals owing to the fact that these stations are in themselves inherently selective and are capable of causing the independent development of vibrations of different frequencies in the elevated conductor and of selectively absorbing the energy of waves of different frequencies even without employing the tuned branch circuits C M and C, L, M."~~ A 30

11 C ~~5~~

Ely D. Insert F^1

Insert F^2

The following amendment is made as the result of a recent interview with the Examiner in charge. Up to the time of that interview applicant had considered it sufficient to point out in his specification,1st,the great necessity of avoiding the effects of magnetic and electro-static hysteresis in the tuned circuits of his invention, 2nd,to specify that the coils should be constructed without iron cores and that solid dielectrics should not be employed in the condensers; 3d,to indicate that the usual forms of coils are not adapted for use in these tuned circuits for the reason of the excessive displacement-currents which tend to flow between conductors charged to a considerable difference of potential,and 4th,to suggest a form of coil in which this effect is less pronounced than in the usual form of coil. Applicant now concurs with the Examiner and feels that the following amendment adds to the completeness of the specification,since it is not necessary to indefinitely diminish the displacement currents in the coil,but suffices to reduce them to the point at which the potential energy

of these displacement currents is small compared to the kinetic energy of the conduction current in the coil for the particular frequency of current with which the coil is to be used.

Insert after page 10 of the specification the following:

"Flat spirals with the turns well separated in order to minimize the displacement currents between the turns are, however, by no means the only form of coils adapted to be used in conjunction with air condensers for the purpose of tuning circuits to high frequencies, and may often be neither the best nor most convenient form of coil to employ. Therefore in defining the character of the coils to be employed for this purpose it will be of advantage to first give the general theoretical considerations which lead to a special construction of the coils and to then give a practical guide to the manner of designing the coils for a particular frequency or range of frequencies.

"A coil or solenoid as usually constructed consists of many turns of cotton or silk insulated wire wound on an insulating core such as a glass or ebonite tube or a wooden spool, the consecutive turns being separated only by the thin insulating coating [illegible]. Such solenoids moreover are in general wound with several layers of wire, the layers also being separated from each other only by the insulating coatings of the wires. Such solenoids are well adapted to be used in conjunction with condensers having solid dielectrics for the purpose of tuning circuits to low frequencies, but neither such coils nor such condensers are available for the purpose of tuning circuits to such high frequencies as are contemplated in the present invention. In the case of high frequencies the energy absorbed in the solid dielectric of the condenser, due to dielectric hysteresis, is excessive, and the displacement currents between the adjacent turns and layers of the coil mask and neutralize the inductance of the coil. Moreover the solid dielectric forming the core of such coils exerts a deleterious effect which in some instances is probably partially due to its possessing a small degree of conductivity, but which must in most instances be ascribed to the high specific inductive capacity of

126 3731

the material and to its dielectric hysteresis.

"In order to tune a circuit to a predetermined high frequency so that it shall show well defined selectivity for that frequency to the exclusion of other frequencies,even to the exclusion of frequencies differing but slightly from the predetermined frequency,it is necessary not only that the condenser shall be free from dielectric hysteresis,but that the coil shall be so constructed as to behave for that frequency practically like a conductor having a fixed resistance and a fixed inductance,but devoid of capacity. Coils constructed in the usual way do not behave for high frequencies as if they had a fixed resistance and inductance and no capacity,but partake more of the character of conductors having distributed resistance,inductance and capacity. In fact they may in some instances behave with high frequencies more like condensers than like conductors having fixed resistance and inductance and no capacity.Since a coil constructed in the usual way behaves for high frequencies as a conductor having distributed resistance,inductance and capacity,it follows that such a coil will show for high frequencies the same quasi-resonance as is observed with low frequencies in long aerial lines and cables,i.e.,that it will per se,and without the intermediary of a condenser show a slight degree of selectivity for some particular frequency and for certain multiples of that frequency,just as a stretched string which has distributed inertia and elasticity,will respond to the particular tone called its fundamental,and to all other tones whose periods are aliquot parts of the periods of that fundamental. But it is not with such quasi-resonance that the present invention is carried into effect,and I wish it understood that I here disclaim any system employing distributed inductance and capacity as a means for tuning the resonant circuits described in this specification.

26/15

A general criterion which determines the utility of a coil for tuning a circuit to a particular high frequency is that the

potential energy of the displacement currents in the coil shall be small compared to the kinetic energy of the conduction current flowing through the coil when the coil is traversed by a current of that frequency.

I have found that for a single layer coil the following procedure is sufficient for practical purposes. Determine the inductance of the coil by formulae to be found in the text books and treatises on electricity and magnetism. This will enable the kinetic energy of the coil to be determined for any particular current and will also permit of the determination of what would be the potential gradient along the coil for the current of the frequency to be employed if the coil were devoid of distributed electrostatic capacity. Next calculate the electrostatic capacity between an end turn and each of the remaining turns of the coil. These capacities together with the potential gradient found will enable the potential energy to be determined, and if the ratio of the potential energy to the kinetic energy so found be negligible compared to unity, the coil will practically satisfy the requirements hereinbefore mentioned. If the coil does not meet the requirements the design should be so changed as to increase the separation between the turns, or the size of the wire should be diminished or the dimensions of the coil so otherwise altered as to decrease the distributed capacity without proportionately diminishing the inductance. The calculations may be greatly abbreviated and the liability to error greatly reduced if the results of the computations be plotted in curves.

"Regarding the effect of a dielectric core in a coil to be used for tuning a circuit to a high frequency, it is sufficient to state that the preferred form of support for such a coil is any skeleton frame which will hold the turns of wire in place without exposing much surface of contact to the wires and affording a minimum of opportunity for the development of displacement currents within itself."

4505-45

Claims:

Amend claim 3 by striking out the word "conveying", line four thereof, and substituting therefor the word "receiving"; by adding the words "at a distance," after the word "waves" in the fifth line thereof, and by striking out the word "to" in line five and substituting the word "in."

Amend claim 4 by striking out the word "carrying", line four thereof and substituting the word "receiving"; by adding the words "at a distance," after the word "waves", in the fifth line thereof; by striking out the word "to" in line six thereof and substituting the word "in" therefor.

Amend claim 5 by striking out the word "conveying" in line four thereof and substituting the word "receiving"; by adding the words "at a distance," after the word "waves" in the fifth line thereof; by striking out the word "to", line six thereof, and substituting the word "in."

Amend claim 6 by striking out the word "carrying", line five thereof, and substituting the word "receiving" therefor; by adding the words "at a distance," after the word "waves" in the sixth line thereof; by striking out the word "to", line six thereof, and substituting the word "in" therefor.

Add the following claims:

"7. The method of tuning a circuit to a given high frequency, which consists in balancing the reactance of an air condenser by the reactance of a coil, the amplitude of whose potential energy is small compared to the amplitude of its kinetic energy when it is supporting a current of said given high frequency.

"8. The method of constructing a coil to be used in a circuit to be tuned to a given high frequency, which consists in so proportioning the coil that the amplitude of its potential energy shall be small compared to the amplitude of its kinetic energy when supporting a current of said given high frequency.

4505-46

"9. The method of developing free or unguided simple harmonic electro-magnetic signal waves, which consists in discharging a condenser through a closed circuit having inductance adapted to produce under such conditions simple harmonic vibrations, and impressing the electrical vibrations so produced upon an open circuit or elevated conductor substantially as described.

"10. The method of developing free or unguided simple harmonic electro-magnetic signal waves which consists in discharging a condenser through a closed circuit having inductance adapted to produce under such conditions simple harmonic vibrations, impressing these vibrations on a resonant circuit or group thereof attuned to the frequency of these vibrations, and impressing the resulting electrical vibrations upon an open circuit or elevated conductor.

"11. The method of selectively receiving the energy of simple harmonic electro-magnetic signal waves of different frequencies, which consists in receiving the same in an elevated conductor and translating or conveying the several energies of the resulting electrical oscillations each to a separate resonant circuit, associated with said elevated conductor and attuned to the frequency of the electro-magnetic waves, the energy of which it is to receive.

"12. The method of selectively receiving the energy of simple harmonic electro-magnetic signal waves of different frequencies which consists in receiving the same in an elevated conductor and translating or conveying the several energies of the resulting electrical oscillations, each to a separate group of resonant circuits, associated with said elevated conductor and attuned to the frequency of the electro-magnetic waves the energy of which it is to receive.

"13. The method of selectively receiving the energy of simple harmonic electro-magnetic signal waves of different frequencies which consists in receiving the same in a plurality of elevated conductors, thereby developing in each elevated conductor electrical oscillations corresponding in frequency to the electro-magnet-

~~ic waves received by it and in translating o conveying from each elevated conductor to an associated resonant circuit the energy of the particular electrical oscillations to the frequency of which said associated circuit is attuned;~~

"14. The method of selectively receiving the energy of simple harmonic electro-magnetic signal waves of different frequencies which consists in receiving the same in a plurality of elevated conductors, thereby developing in each elevated conductor electrical oscillations corresponding in frequency to the electro-magnetic waves received by it and in translating or conveying from each elevated conductor to a group of resonant circuits associated therewith the energy of the particular electrical oscillations to the frequency of which said group of associated resonant circuits is attuned."

Reply to the rejections upon references is made for convenience in a separate paper.

Respy
Alvo P. Browne
atty for applt

5 001

IN THE UNITED STATES PATENT OFFICE.

Room No.91. Serial No.4555.

Application of John Stone Stone,

For Patent for Improvement in ~~Apparatus for~~ Method of Selective Electric Signalling.

Filed ~~January 23,1901~~. Feb 8 1900

In reply to Office letter of April 10,1901.

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51 State street, Boston,

April 8,1901.

To the Commissioner of Patents,

Washington, D.C.

Sir:

In reply to references cited by the Patent Office.

Claim 1 having been rejected upon the patent to Pupin, No 640,515 of January 2,1900, applicant respectfully submits that the specification of the Pupin patent was written in 1895 as appears on its face and that it is only in the light of the subsequent advance of the art and of the present invention that anything contained in the Pupin patent could possibly have been construed to suggest a system for developing free or unguided forced simple harmonic signal waves emanating from an elevated conductor used as a radiator, and passing out from it to great distances through the surrounding atmosphere in the form of radient energy. The object of the Pupin invention is in fact to develop practically independently in a single line conductor, two currents of different frequencies in order that these two currents may be used for duplex telegraphy by being selectively received in seperated branch circuits at the receiving end of the line, each branch circuit being tuned to the frequency of one of said alternating currents

If, however, the apparatus described in Pupin's patent for

developing currents of different frequencies in a line conductor could be employed to develop the electrical vibrations in the elevated conductors or radiators of applicant's present invention, then it might be alleged that Pupin's invention had a double use to which he was entitled even though he did not apprehend it at the time of filing his application, or did not consider it worth claiming or even mentioning in his specification. But the apparatus of the Pupin patent is not, in the present state of the art, capable of being employed for the development of the electro-magnetic signal waves described by applicant in his specification. This is for the reason that the lengths of waves generated by the means described in the Pupin patent are of the order of 10^3 as compared with those which in the present state of the art are available for the purposes of the present invention. In the present state of the art such frequencies as are capable of being developed by the only apparatus described or suggested in the Pupin patent, if impressed upon an elevated conductor of practicable dimensions would produce no appreciable radiation of energy, i.e., the resulting electrical vibrations in the elevated conductor would give rise to practically no free or unguided electro-magnetic waves. There would be but a negligible amount of the energy which would emanate from the oscillator never to return to it. Practically all the energy would be confined to the neighborhood of the oscillator and would flow out and back with each oscillation.

Now if in the immediate future it be shown that by the use of a specially constructed elevated conductor, the apparatus described or implied in the Pupin patent becomes available as a practical means of developing electro-magnetic waves of practical utility [illegible] wireless telegraphy, then the method of so specially constructing [illegible] elevated conductor may, [illegible] in the judgment of the applicant will, itself involve invention, [illegible] specially constructed elevated conductor when used with [illegible] patent [illegible] in like manner constitute a patentable invention.

Claim 2 having been rejected upon the patent to Marconi No. 627,650 of June 27,1899,applicant respectfully submits that in the first place the object of the Marconi patent was not to selectively receive the energy of electro-magnetic waves of one frequency to the exclusion of the energy of waves of other frequencies.

His object was to overcome certain inherent difficulties in the system which he had previously been employing. In that earlier system the elevated conductor (which in the patent cited as a reference he styles a capacity) was connected to the earth through the coherer,and the static charges,owing to atmospheric electricity,which accumulated upon the elevated conductor discharging through the coherer seriously interfered with the proper operation of the system. In order to overcome this difficulty,Mr. Marconi placed the coherer in a branch or local circuit,not conductively connected with the elevated conductor,and grounded the elevated conductor through a coil. The static charges accumulated by the elevated conductor were thereby permitted to readily pass to earth without interfering with the operation of the coherer.

Mr.Marconi must have been perfectly aware,at the time of filing of his application for the patent now cited as a reference in this case,of the great practical importance of securing a selective system of space telegraphy,and yet we find in this patent no reference to such a system,and it is only by implication and in the light of applicant's specification that a passage in the Marconi patent can be construed to indicate that Marconi had any intention of disclosing in this patent the invention sought to be covered in claim 2 of the present application. But as will hereinafter be fully and clearly shown,the above referred to passage in Marconi's patent has a well defined meaning of its own and any other interpretation of it is wholly unwarranted. Mr.Marconi did not consider the invention of the patent cited as a solution of the problem of selectively receiving the energy of simple harmonic electro-magnetic signal waves of one frequency to the exclusion of those of other frequencies,and therefore did not in this patent

claim to have [illegible] important invention. If he had con- [illegible] his invention a solution of so important a problem, he would not have published the solution in his patent without claiming it, and would not have satisfied himself with the claims he did make.

It may be contended that though Marconi did not at the time of filing his application, know that his apparatus could, or intend that it should, be used for selectively receiving the energy of simple harmonic electro-magnetic waves of one frequency to the exclusion of those of other frequencies, yet the apparatus of his patent is capable of such use, and that therefore his patent constituted a publication of such a system of selectively receiving the energy of simple harmonic waves of one frequency to the exclusion of waves of other frequencies.

The answer to such a contention is that the Marconi patent does not disclose a system which could operate to selectively receive the energy of waves of one frequency to the exclusion of the energy of those of other frequencies. The instructions contained in this patent are sufficiently explicit to forbid such an hypothesis.

These instructions as to the manner of constructing the coil make the apparatus incapable of such use, and furthermore we must note in the specification the absence of any specific instruction as to the proper conditions for the tuning of circuits to such high frequencies as are involved in the present invention. The Marconi specification specifically instructs us, both in text and drawing, to construct the induction coil of fine insulated wire, in very much the same manner as solenoids are usually constructed in practice, with the turns close together; and particular stress is laid upon the importance of having the primary and secondary quite close to each other. This practically instructs us to wind the secondary immediately upon the primary. Owing to the displacement currents which take place in the case of high frequencies, where precautions are not taken to prevent them, such a coil would behave more like a condenser than like a coil. It would be absolutely

impossible to balance the reactance of such a coil by the reactance of a condenser for high frequencies.

Furthermore the entire absence from the Marconi specification of any instructions concerning the necessity of avoiding the effects of electrostatic and magnetic hysteresis, and the effects of displacement currents in the apparatus constituting the branch circuit, which includes the coherer, would of itself preclude the Marconi patent from being properly regarded as in any way a disclosure of the invention sought to be claimed by applicant.

The passage in the Marconi specification before mentioned, in which there might seem to be some hint of a selective system, is: "It is desirable" (note, not essential) "that the induction coil should be in tune or syntony with the electrical oscillations transmitted, the most appropriate number of turns and the most appropriate thickness of wire varying with the length of wave of the oscillations transmitted."

The real meaning of this passage is that the organization described in the patent is capable of receiving the waves, whatever be their length within practical limits, but that the apparatus will be more efficient for this purpose if the coil is tuned to the frequency of the waves to be received. It has long been known that the impedance of an induction coil may to a certain limited extent [illegible] the apparent impedance of the coil for a certain frequency called the fundamental and for the harmonies or overtones of that fundamental as compared with other frequencies. The acoustical analogue of this is familiar, namely the stretched string vibrating most readily to its fundamental and to notes having periods which are [illegible] aliquot parts of the period of the fundamental.

[illegible] the operation of the organization described in the Marconi patent, it is certain that owing to the manner in which the induction coil is constructed, it does not operate as a simple [illegible] practically in [illegible] oscillations in the [illegible] branch circuit containing the coherer, but [illegible]

combination of a conden[illegible] [illegible]il by which the [illegible]lations in the elevated [illegible] [illegible]ted through the [illegible] circuit in passing to the [illegible]tion.

Claims 3 and 4 each [illegible] the Swiss patent [illegible] Braun, No.18,577 of June [illegible] view of the United [illegible] patent to Pupin No.6[illegible] [illegible]1900, and it is implied in the Office action of [illegible] this action is taken [illegible] cause the applic[illegible] [illegible]ethod of developing simple harmonic waves [illegible] Braun system is unpatentable. Applicant resp[illegible] [illegible] that he has not seen the Braun Swiss patent cit[illegible] [illegible]t he has [illegible] access to and examined copy of the [illegible] [illegible]tent to Braun No.1862 of 1899, which [illegible] later date [illegible] he believes to be for the same invention as the Swiss patent cited. Applicant fails to see what [illegible] either of these patents can have upon that part of [illegible] or claim 4 which relates to the selective reception [illegible] of waves of different frequencies, each in a separate receiving station, since both the Pupin and Braun patents [illegible] apparatus to be used at transmitting stations.

Applicant finds that the object of the Braun invention is [illegible] obtain free or unguided electro-magnetic signal waves of greater length than those given by a Hertz oscillator, and this he [illegible] to accomplish in order that the signals may less easily be obstructed in their passage from the transmitting to the receiving station by intervening obstacles such as houses, hills, etc.

For this purpose it was wholly unnecessary that Braun's signal waves should be simple harmonic in character, [illegible] fication he makes no provision that they shall be simple [illegible] in character.

Applicant has already argued in his letter to the Office of March 23, 1901 that the electric vibrations in the apparatus disclosed by Braun are the natural vibrations of a system of at least two degrees of freedom and are in general therefore not of a simple harmonic character. This point does not seem to be contended by the Examiner. In view of the fact that the Examiner has again rejected [illegible] 7 upon the patent to Braun in view of the patent to

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Applicant now further points out that there is not even an allusion in the Braun disclosure to the necessity of guarding against the effects of electrostatic and magnetic hysteresis in the associated circuits, and since there is no hint in Braun's disclosure of the importance of so constructing the coils as to avoid the effects of displacement currents, one seeking to practice the invention of the Braun patent would employ the usual forms of coil and condenser. Such apparatus, though it might operate to accomplish the results sought by Braun, would be wholly unsuited to perform the functions of the apparatus of the present application. The apparatus of the Braun patent is simply a combination of the Tesla apparatus for producing high frequency currents with the elevated conductor as radiator of a wireless telegraph station to form a wireless telegraph transmitting station sending out waves if greater length than those theretofore employed in wireless telegraph stations of the elevated conductor type.

Applicant contends that in order to properly tune the circuits described in his application, either the auxilliary coils L, L', L'', etc., must be included in those circuits, or the induction coils M, M', M'', etc., must be so specially constructed as to furnish the auxilliary inductance which these coils impart to the circuit. Moreover the most strict attention must be given to the exclusion of electrostatic and magnetic hysteresis in these circuits.

Resp'y
Alex P. Browne
atty for appl't

2600

7600

4-5-03

Amendt. D

Apr. 12

IN THE UNITED STATES PATENT OFFICE.

Room No. 31, Serial No. ,

Application of John

For Patent for Improvements in Detective

Filed 8-15, 1900

In reply to Office letter of 1901.

----

31 State street, Boston,

April 11, 1902.

To the Commissioner of Patents,

Washington, D.C.

Sir:

drawings referred to at page 3, line 14, page 3, line 1, of my letter of amendment of the 9th instant.

Respectfully,

Alex. P. Browne

Att'y. for Applicant.

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Paper No. 91
All communications should be addressed to
The Commissioner of Patents,
Washington, D. C.

Paper No. 9
All communications respecting this application should give the serial number, date of filing, and title of invention.

DEPARTMENT OF THE INTERIOR.
UNITED STATES PATENT OFFICE,
WASHINGTON, D. C. May 13, 1902.

432

John Stone Stone,
Care, Watson & Watson,
Washington, D.C.

Please find below a communication from the **EXAMINER** *in charge of your application,*
Ser. No. 4505, for Method of Selective Electric Signalling, filed Feb. 8, 1900,

F. I. Allen
Commissioner of Patents.

This action is in response to applicant's communication filed Apl. 11 and 12, 1902.

It is evident that the original specification in view of the state of the art would justify the addition of views showing two local circuits tuned to different frequencies inductively connected to a single aperiodic sending or receiving conductor, but it is obvious that the present showing of specifically novel modifications of parallel and series tuned conductively connected branch circuits is specifically new matter for which there was no adequate foundation in the case as originally filed.

Additional illustration should therefore be limited to the unobjectionable form and the present new illustration presented, if at all, in a new application. It seems evident that many specific claims could be drawn to the apparatus now shown that would be clearly patentable over the disclosure in the case as originally presented.

The grounded conductor VK should therefore be shown as a single straight wire broken only by the secondary windings I_2, the induction coils L, L_1 and condensers C, C' being omitted therefrom.

If it should appear that the presence of the two transformer secondaries in the sending and receiving conductors give them a pronounced fundamental or natural period so that the shunt conden-

ser pets and the inductance coils I1, I2 are necessary to operativeness, then it will be evident that it requires invention to use two locals on one vertical conductor and all reference to such modification would have to be eliminated. [illegible] thought to be the case, however, and the present requirement is limited to that of the last preceding paragraph. In this connection it is pointed out that applicant has shown on the new drawings an arrangement of coherer and translating device in connection with a Planté cell and that he has in the amendment referred to a certain "skeleton frame" for [illegible] the dielectric core of the coil. This matter having no foundation in the original specification must be objected to as involving a departure from the original disclosure and cancellation is required. The fact that applicant has in a co-pending application filed about one year after the filing of this case stated that the skeleton coil is well known in the art, [illegible] giving reference to the publication wherein a description [illegible] found, cannot be availed of [illegible] case [illegible] the objection [illegible] the date of the publication [illegible] is [illegible] later than that [illegible]

[illegible] foundation of what was stated or [illegible] in the original specification. The original specification points [illegible] that electro-static and magnetic hysteresis must be carefully [illegible] [illegible]

[illegible] should be eliminated.

[illegible]

that can be relied upon for patentability of claims 7 and 8 over the patent to Lodge, 609,154, Aug. 16, 1898, of record, and as that is new to this application it must be objected to as new matter.

Page 16, line 3, "current" should be changed to <u>circuit</u>.

Certain of the claims, such as claim 1, involve an argument the soundness of which the Office has no means of testing. Assuming that the simple harmonic wave can be produced in a closed vibrator, it does not necessarily follow that such simple harmonic wave can be transferred to the elevated conductor and from the latter to the ether without change of form. The fact is that applicant has undoubtedly improved the form of wave by the use of closed tuned circuits having an <u>extra loading coil</u> and the Office is not in a position to affirm or deny anything more than this. Because of the undoubted improvements involved in the apparatus upon which the claim is based it is allowed, and all other claims containing the same implication of novel features will be allowed.

Claim 2 is on a different basis. It can take nothing from the words "simple harmonic" because it has long been understood that a circuit tuned to respond to a given fundamental frequency will always be more efficient when acted upon by a simple harmonic of said frequency. This claim is alternative in substance and objectionable for that reason, the function of one resonant circuit being different from that of a group of resonant circuits in so much as the former lacks the weeding out action of the latter. Considering it as concerning the first alternative it is met in Marconi, 627,650, June 27, 1899, of record. Tuning is never perfect and in order to avoid this reference it is necessary to show affirmatively that there can be no tuning possible with his construction. He gives full particulars and details of construction and there can be no difficulty in proving mathematically whether or not any tuning effect is possible with his apparatus. Claim 2 is also rejected on Lodge aforesaid, in which the waves received

are probably not simple harmonic. In connection with figure 12 a condenser is described as a substitute for the resistance w for connecting the coherer more closely with the receiving apparatus whereby it is stimulated. On page 1 it is stated as to the telegraph instrument that it is associated with a "subsidiary circuit capable of electric oscillations of the same particular frequency" as the sending station.

Claim 7 is rejected on Lodge aforesaid, wherein an open coil balances the capacity of the air condenser in which the area h is one plate and the ground the other.

Claim 8 is also rejected on the same patent, special reference being had to lines 17 to 29 of page 3.

Claim 11 differs from claim 2 only in that it specifies a plurality of resonant circuits associated with the elevated conductor. The latter feature was admitted in the description only because it did not involve invention in view of Pupin's multiplex system of telegraphy described in patent No. 640,515, and the claim which is otherwi[illegible]e same as said claim 2 must be rejected on the same reference a[illegible]for the same reasons.

Claims 7 and 8 are also rejected as involving new matter.

Claim 13 is merely for the use of Marconi's apparatus in the art pointed out by Lodge and it is accordingly rejected.

Claims 1, 3, 4, 5, 6, 9, 10, 12 and 14 are capable of an interpretation which would make them definitive of applicant's invention. They are accordingly allowed.

Examiner, Div. 16.

3348

Amendt 2 May 31

IN THE UNITED STATES PATENT OFFICE.

[illegible] No.91, Serial No.4,505,

[illegible]lication of John Stone Stone,

[illegible] Patent for Improvement in Method of Selective Electric Signaling,

Filed [illegible]bruary 9,1900,

In reply to Office letter of May 13,1902.

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31 State street,Boston,Mass.,

May 28,1902.

[illegible]ner of Patents,

Washington,D.C.

The case is amended as follows:

[illegible] 11 of the specification,line 20,erase "Fig.9" and sub[illegible] therefor "Figs.9 and 15."

[illegible] 16,line [illegible],change "current" to "circuit."

[illegible] 17 of [illegible]cation,line 5,erase "Fig.9" and sub[illegible]."

[illegible],erase [illegible] and substitute "Figs.3 and 15."

[illegible] of [illegible] amendment of April 8,190[illegible],lines 17 and 18, [illegible] "preferred" and substitute therefor the word "Several."

[illegible]4,erase the number "1[illegible]" and substitute therefor the [illegible]

[illegible],erase the number "16" and substitute therefor the [illegible]

[illegible] amendment of April 8,190[illegible],erase lines 1 and 2.

[illegible]1,erase the word "and" [illegible] substitute therefor

a comma (",") introduce after the number "6" the word and number "and 17."

Line 3, erase word "and" and after the number "8" insert "and [illegible]".

Line [illegible], erase the word "and" and substitute a comma (",") after number "[illegible]" insert "and [illegible]."

Line 11, erase the number [illegible] and substitute the number "[illegible]."

Line 14, erase the number [illegible] and substitute the number "17."

Line 18, erase the word "and" and substitute therefor a comma ","; introduce the word and number "and 17" after the number "16"

Line [illegible], erase the number [illegible] and substitute therefor the number "16."

Line 27, erase the number "16" and substitute therefor the number "17."

Line 30, erase the number [illegible] and substitute the number "16."

Page 5 [illegible] erase from the letter [illegible] reference [illegible] letters [illegible].

Erase [illegible] L M [illegible] to the end of the paragraph.

Line [illegible], erase the number "16" and substitute the number "17."

Line [illegible], erase from "[illegible]" through "that."

Lines [illegible] and [illegible], erase "communicated only to" and substitute therefor "absorbed by."

Line [illegible], erase "that."

Lines [illegible], erase "communicated only to" and substitute therefor "absorbed by."

Line [illegible], erase from "[illegible]" through "the usual manner" on [illegible] line [illegible].

Page [illegible], line [illegible], after the word "are" insert "not described as [illegible]."

[illegible], erase from "even without" [illegible] [illegible].

[illegible] of the drawing and substitute the two [illegible].

For the sake of clearness, claims 2,7,8,11, and 13 are canceled and the following substitute claims are filed:

"2. The method of absorbing the energy of free or unguided, simple harmonic, electro-magnetic signal waves of one frequency, to the exclusion of the energy of like waves of a different frequency, which consists in associating with an elevated conductor a circuit resonant to the frequency of the waves, the energy of which is to be absorbed.

"7. The method of rendering a circuit resonant to a given high frequency, which consists in balancing the reactance of an air condenser by the reactance of a coil, ~~in~~ the amplitude of whose potential energy is small compared to the amplitude of its kinetic energy when it is supporting a current of said given high frequency.

"8. The method of constructing a coil to be used in a circuit to be resonant to a given high frequency, which consists in so proportioning the coil that the amplitude of its potential energy shall be small compared to the amplitude of its kinetic energy when supporting a current of given high frequency.

"11. The method of selectively receiving the energy of free or unguided simple harmonic electro-magnetic signal waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in an elevated conductor and translating or conveying the several energies of the resulting electrical oscillations, each to a separate circuit associated with said elevated conductor, and resonant to the frequency of the electro-magnetic waves, the energy of which it is to receive.

"13. The method of selectively receiving the energy of free or unguided simple-harmonic electro-magnetic signal waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in a plurality of elevated conductors, thereby developing in each elevated conductor electrical oscillations corresponding in frequency to the electro-magnetic waves received by it and in translating or conveying from each elevated conductor to an associated circuit [illegible]

electrical oscillation to the frequency of which said associated circuit is made resonant."

Add the following claims:

15 ~~"17.~~ The method of absorbing the energy of free or unguided simple harmonic electro-magnetic signal waves of one frequency to the exclusion of the energy of like waves of different frequencies which consists in associating with an elevated conductor a group of circuits, each resonant to the frequency of the waves, the energy of which is to be absorbed.

16 "16. The method of receiving the energy of simple harmonic electro-magnetic signal waves, which consists in receiving the same in an elevated conductor and translating or conveying the energy of the resulting electrical oscillations to an electrical translating device shunted around the terminals of one of the elements of a resonant circuit associated with said elevated conductor and attuned to the frequency of the electro-magnetic waves."

IN THE UNITED STATES PATENT OFFICE.

Room No.91, Serial No.4,505,

Application of John Stone Stone,

For Patent for Improvement in Method of Selective Electric Signaling,

Filed February 8,1900,

In reply to Office letter of May 13,1902.

----

31 State street,Boston,Mass.,

May 28,1902.

Commissioner of Patents,

Washington,D.C.

Sir:

With reference to the criticisms of the Examiner as to new matter,it is believed that none of them is well founded. The matter of inductive or conductive connection of circuits as well known alternatives is referred to on page 7 of the original specification in the early part of the paragraph beginning "In general if n simple circuits," etc.

Regarding the use of a Plante battery in lieu of a condenser of large capacity,it is to be observed that the equivalence of these two devices for such purposes as the exclusion of a battery current from a circuit and the suppression of sparks at contacts was well recognized many years before the date of filing of the present application. The Examiner is respectfully referred to "Alternate Currents of Electricity" by Blakesley,published in 1885,in which the equivalence of a condenser of large but variable capacity and an electro-lytic cell is very closely and interestingly set forth. Moreover,on page 13,lines 2 to 7,inclusive,of the present specification as originally filed,the Examiner will find an instance in which applicant mentions a Plante battery and a condenser of large capacity as alternate forms. 4565-65

However, to facilitate the examination of the case, applicant has decided to accept the suggestion of the Examiner to cancel Figs. 13 to 16 and substitute therefor new figures 13 to 17 sent herewith. To render the specification accurately descriptive of the new drawings, an amendment to it is also made, which for convenience is placed upon a separate paper.

The Examiner refers to the illustrative example of a precaution to be taken set forth in lines 14 to 16 of page 19 as a basis for his objection to the present specific statement that solid dielectrics should be eliminated as far as possible from the coils. Particular attention is called to the fact that the descriptive matter referred to is preceded by the broad unqualified statement that both electrostatic and magnetic hysteresis must be excluded from the resonant circuit.

Properly viewed, the reference to exclusion of solid dielectrics from the coils is merely a specific restatement of the above co-ordinate with and as much justified as the statements in lines 14 to 16, above quoted. There being adequate ground for the statement that solid dielectrics should so far as possible be excluded from the coils, the suggestion of a skeleton frame as an obvious expedient is entirely unimportant and further objection should not be urged.

Applicant cannot concede the validity of the Examiner's ruling as to the phrase "small as compared to the kinetic energy" introduced into the specification [illegible] application by recent amendment. The Examiner rightly states, however, that the original disclosure of applicant justifies the description of the potential energy of the displacement currents in the coil by the word "small." Now this word "small" involves comparison, and comparison with things of like kind, and it seems clear therefore to applicant that when it is stated that the potential energy is small as compared to the kinetic energy, this is merely a more accurate restatement of the fact that the potential energy is small. The patent to Lodge, No. 609,154, shows [illegible] in

4 [illegible]

which the potential energy of displacement currents shall be small. In fact what is shown in that patent excludes any such idea.

The only passages in the Lodge patent cited which gives particular instruction with regard to the construction of the coils he employs, are as follows:

"Between either capacity area and its knob I place a syntonizing self-inductance coil - that is, a coil of wire or metallic ribbon h', preferably insulated with any solid or fluid insulator, as in Fig. 2, or in air, of shape suitable to attain greatest inductance with a given amount of resistance."

Again.

"In Fig. 7 the syntonizing-coil h' is shown as surrounding a large telegraph-insulator y."

Again.

"The self-inductance-coil represented at h' in all applicable figures is a coil of highly conducting wire or ribbon, well insulated by air or by some other medium, as already described, or else covered to a sufficient thickness with insulating material of such shape as to have maximum self-inductance for a given resistance, and it may be either a flat coil including a considerable plane area or it may be a cylindrical coil wound upon a finely-subdivided iron core, as shown at m in Fig. 3, the core being either ring-shaped or U-shaped or straight."

With reference to the Examiner's criticism of claims 2, 11 and 13, applicant respectfully suggests that the Examiner must have overlooked the distinction heretofore made in the case between a circuit made resonant by adding a coil and a condenser, and the quasi resonance obtained by efforts to regulate both the capacity and inductance of the coil itself, which is apparently what is sought to be done by Marconi in his patent No. 627,650. The result of such quasi resonance, even if successfully obtained, will not be the absorbing or selective receiving of the energy of waves of one frequency to the exclusion of the energy of those of other fre-

quencies, and no method is disclosed in any of the references involving the employment of resonant circuits as distinguished from quasi resonant coils, in the manner and for the purposes disclosed by the applicant.

Applicant has disclaimed such quasi resonance in which distributed electro-static capacity of the coil itself is employed to diminish the impedence of the coil, because such distributed capacity diminishes the impedance of the coil not alone for one frequency, but for a very large number of frequencies, and is therefore not available for the purpose of making a circuit resonant to one frequency to the exclusion of other frequencies.

Applicant does not contend that there is no advantage to be gained by such a construction as that shown in the Marconi patent cited. He only contends that it is not useful for the purpose of selective signaling, where waves of one frequency are received to the exclusion of waves of other frequencies.

The Marconi patent cited does not profess to be for a system of selective signaling and is incapable of use as a selective system.

It does, however disclose a system whereby disturbance from atmospheric electricity is minimized, and is, in the opinion of applicant, adapted to such use.

It is believed that some of the claims may with advantage be amended for the sake of greater clearness, and that certain claims may well be added. These amendments and additions are also for convenience made in the separate paper before referred to.

With reference to the applicant's action in canceling Figs. 15 to 16, he begs to have it understood that he is advised that these Figures may contain certain novel arrangements which may be in themselves patentable to him, and hence that their cancelation in this case is not to be regarded as abandonment, [illegible].

Respectfully,

[illegible]

Atty for applt.

H505

Fig. 9.

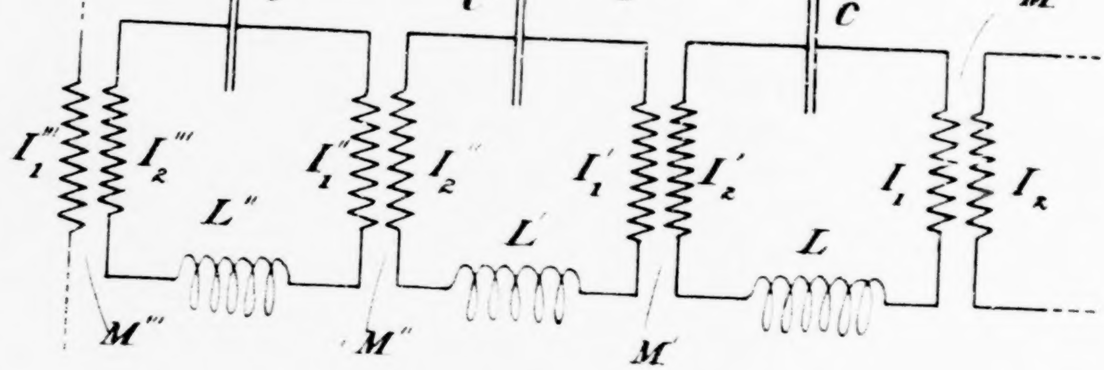


Fig. 10.

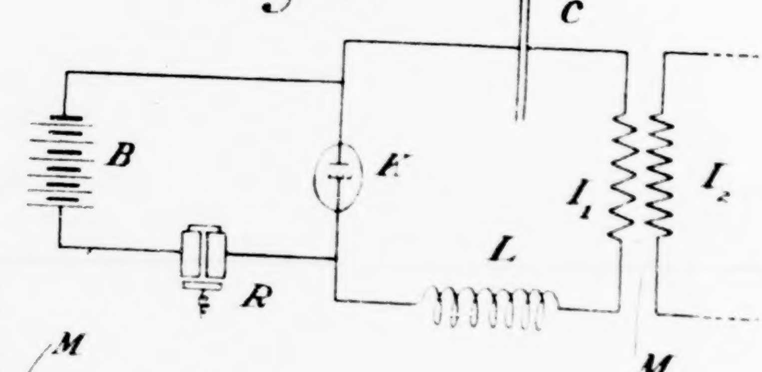


Fig. 11.

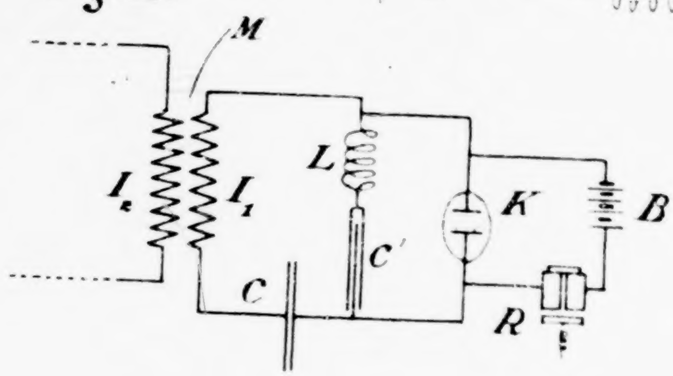
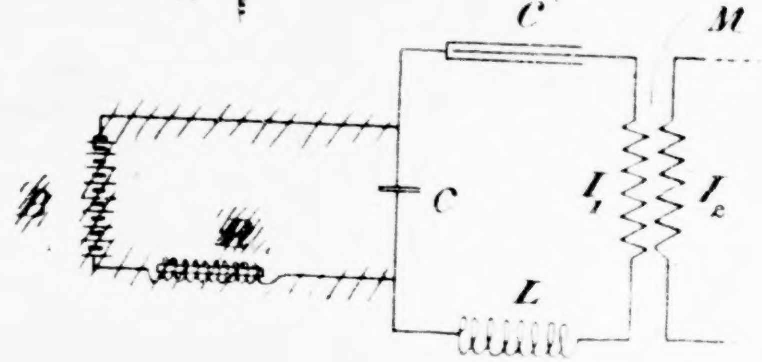


Fig. 12.



WITNESSES:

INVENTOR

Argument [illegible] 12
June 9 2

IN THE UNITED STATES PATENT OFFICE.

Room No.91, Serial No.4500,

Application of John Stone Stone,

For Patent for Improvement in Method of Selective

Electric Signaling,

Filed February [illegible],1900,

In reply to Office letter of May 12,1902.

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31 State street,Boston,

June 7 ,1902.

To the Commissioner of Patents,

Washington,D.C.

Sir:

Applicant finds that through an oversight in the typewriting of his argument of date May 28,1902,an explanatory passage has been omitted after the paragraph ending on line 24,page 3 thereof.

The paragraph thus omitted is explanatory of the bearing of the [illegible] the United States patent to Lodge No.609,154, [illegible] in said argument of May 28th,and is as follows:

" [illegible] ratio of the inductance of the coil to its resistance large. He disregards the displacement currents between the turns entirely. His instructions to use metallic ribbon, [illegible] fluid (liquid) insulation,to wind the coil on a large telegraph insulator instead of a skeleton frame,to wind the coil upon a finely subdivided iron core,are all [illegible] to forbid the use of such coils as are described in claims 7 and 8 of the present specification."

Applicant therefore now submits the above quoted passage as having the bearing of the Lodge patent of record upon the special construction of coil [illegible] by the applicant.

Applicant further notes that in his argument of May 28,1902 he did not meet, or more properly speaking, comment upon the following passage in the Office letter of May 13,1902.

"Certain of the claims, such as claim 1, involve an argument, "the soundness of which the Office has no means of testing. Assuming that the simple harmonic wave can be produced in a closed vi- "brator, it does not necessarily follow that such simple harmonic "wave can be transferred to the elevated conductor and from the "latter to the ether without change of form. The fact is that "applicant has undoubtedly improved the form of wave by the use of "closed tuned circuits having an extra loading coil and the Office "is not in a position to affirm or deny anything more than this. "Because of the undoubted improvement involved in the apparatus "upon which the claim is based, it is allowed, and all other claims "containing the same implication of novel feature will be allowed."

Applicant concurs with the Examiner in his view that if simple harmonic electric vibrations can be developed in a closed, i.e, a persistent, vibrator, it is not obvious that these vibrations can be transferred to the elevated conductor of a wireless telegraph system and thereby develop in the ether free or unguided, electromagnetic waves or radiation, also of a simple harmonic character.

But though such method of developing free or unguided electro magnetic waves or radiation of a simple harmonic character is not obvious, applicant nevertheless contends that he has proved, both by mathematical argument and by experiments, that if forced simple harmonic electric vibrations be impressed upon the elevated conductor of a wireless telegraph system, the resulting radiation of electric and magnetic force will also be simple harmonic and of the same frequency.

So far as the applicant is aware he was the first to discover and make public this fact.

He states that the mere fact that the electric vibrations which take place in the associated persistent oscillator are simple harmonic in character and that the vibations which take place in the elevated conductor are the <u>forced vibrations</u> which result

from impressing these simple harmonic vibrations on the elevated conductor, is enough to insure that the electric vibrations in the elevated conductor are also simple harmonic with respect to time and are of the same frequency as those of the oscillator which developed them. Because it has long been known that if a simple harmonic force act upon a mechanical or electric system, be it ever so complex in structure, the resulting forced vibrations will also be simple harmonic in character and of the same frequency as the force which gave them birth, except in the case where there is hysteresis. But in the case of an a[illegible] the elevated conductor of a wireless telegraph system there is no hysteresis present, and the forced electric vibrations of the elevated conductor must therefore be of the same form and frequency as the vibrations of the oscillator which communicated them to the elevated conductor.

In respect to the foregoing, the Examiner is respectfully referred to the definition of forced vibration given in "The Theory of Electricity and Magnetism" by A. G. Webster, Article 248, page 489, which is as follows:

> "An oscillation whose period is that of force, as in our "present case, is called a forced oscillation or vibration in "contra-distinction to the case of the previous section, where "no force being applied, the period is governed by the con"stants of the system, and the oscillation is called a free "oscillation."

Also "The Theory of Sound" by Lord Rayleigh, First Edition, 1877, Article 46, pages 41 and 42, which is as follows:

> "The distinction between forced and free vibrations is "very important, and must be clearly understood. The period "of the former is determined wholly by the force which is "supposed to act on the system from without; while that of "the latter depends only on the constitution of the system "itself. Another point of difference is that so long as the "external influence continues to operate, a forced vibration "is permanent, being represented strictly by a harmonic func"tion, but a free vibration gradually dies away, becoming "negligible after a time."

Also the present application, page 8, lines 10 to 23:

"But besides the ability to execute natural vibrations "or oscillations, both electric and mechanical systems are "capable of supporting what are termed forced vibrations and "in the case of forced vibrations, the period of the vibration "is independent of the electro-magnetic constants of the cir- "cuit on the one hand, and the mechanical constants of the me- "chanical system on the other hand, and depends only upon the "period of the impressed force. Thus if a simple harmonic "electro-motive force be impressed upon a circuit free from "hysteresis, whether it be a simple circuit, or a complex of "simple circuits, the forced vibrations or currents resulting "from this impressed force will also be simple harmonic, and "of the same period as that of the impressed force."

Also present application, page 10, lines 19 to 26:

"In order that the vertical conductor at the transmit- "ting station shall generate harmonic electro-magnetic waves "of but a single frequency, I cause the electric vibrations "in the conductor to be of a simple harmonic character and "this in turn I accomplish by producing what are substantial- "ly forced electric vibrations in the vertical conductor in "lieu of producing natural vibrations in the conductor as "has heretofore been practised."

Although it may be thus shown that the vibrations of the vertical conductor are forced simple harmonic electric vibrations of the same frequency as those impressed upon it by the associated [illegible] oscillator, it is still not obvious that the free or unguided electro-magnetic waves or radiation will also be of a simple harmonic character and of the same frequency as the electric vibrations in the elevated conductor. Fortunately, however, for [illegible] purpose, the discussion of the Hertz oscillator, as given by [illegible], may be made available to show that the electro-magnetic waves [illegible] are simple harmonic in character and of the same [illegible] as the vibrations in the elevated conductor. Though the

Though the electric vibrations which Dr.Hertz employed in his experiments with what is known as his dumb bell oscillator,were not forced simple harmonic vibrations,but were the natural vibrations of the oscillator,nevertheless in his mathematical interpretation of his results,he employed a solution strictly applicable only to the case of forced simple harmonic vibrations in the oscillator.

In order not to encumber the case with lengthy mathematical expressions,the Examiner is asked to consult either "Electric Waves," by Dr.Heinrich Hertz,in the original or in the translation by D.E. Jones, Macmillan & Co.,1893; "The Theory of Light," by Thomas Preston, Second Edition,1895; or "Absolute Measurements in Electricity and Magnetism," by A.Gray,1893,Vol.2,part 2,chap.14,section 2,in each of which Hertz' analysis of the operation of his dumb bell oscillator,when executing simple harmonic electric vibrations,is given. By referring to the equations for the electric and magnetic forces in the medium surrounding the oscillator,the Examiner will find that in the equatorial plane of the oscillator,however far it be extended,the magnetic force is always parallel to the plane,that the electric force is always normal to the plane,and that the potential is zero throughout the plane. It follows directly from these considerations that if a conducting sheet be extended through this equatorial plane,no current will be developed in the sheet and no disturbance of the field of force can result,since no lines of magnetic force will cut the conducting sheet, and there will be no component of electric force parallel to the sheet. If the conducting sheet be infinitely conductive,it follows that all that goes on below the sheet may be eliminated,leaving only a conductor extending vertically from the conducting sheet,and bearing at its extremity a capacity area. Such an arrangement is substantially the same as the vertically elevated conductor of a wireless telegraph system extending vertically from the conductive surface of the earth and bearing a capacity area at its extremity. It follows,therefore,that the solution given by Dr.Hertz for the radiation emanating from his dumb bell oscillator executing simple harmonic vibrations is directly applicable to the problem of an elevated conductor in a wireless telegraph system

executing simple harmonic electric vibrations. Now since simple harmonic electric vibrations in the Hertz oscillator give rise to simple harmonic electro magnetic radiation, so also must simple harmonic electric vibrations in the elevated conductor of a wireless telegraph system give rise to simple harmonic electro magnetic radiation.

These considerations show, therefore, that the forced simple harmonic electric vibrations of the elevated conductor would give birth to electro-magnetic waves, also simple harmonic in character, and of the same period as the electric vibrations forced in the elevated conductor

So far as applicant is aware, he was the first to discover and point out the application of Hertz' analysis to the elevated conductor of a wireless telegraph system.

Applicant feels that this argument is sufficient comment upon the paragraph quoted at the beginning of this letter from the Office letter of May 13,1902. Nevertheless, it is worth noting that he does not contend that either the vibrations in the elevated conductor, or the radiations emanating therefrom, are absolutely simple harmonic in character, such perfection of wave form being unattainable in any practical apparatus. Moreover, when a simple harmonic force is impressed upon a system having a natural rate of vibration of its own, there is always more or less of the natural vibration developed, and it is worth noting that in the important cases when the elevated conductor of a wireless telegraph system has a fundamental which is of the same frequency as the forced vibrations impressed upon it, the natural vibrations excited will not interfere with the wave form. Again if the elevated conductor be aperiodic, no natural vibrations will be set up in it when the forced vibrations are impressed, and the form of the forced vibrations will therefore not be disturbed. It is only in the case where the elevated conductor has a very pronounced selectivity of its own, that the impressing of forced vibrations upon it of a different frequency from its natural frequency will develop natural vibrations seriously interfering with the wave form of the vibrations developed in it.

It will also be noted that in the above discussion, in passing from the consideration of the Hertz oscillator to the consideration of

the vertical wire oscillator, the conducting sheet supposed to extend through the equatorial plane, was assumed to be infinitely conductive, and could bot, therefore, represent with absolute accuracy the surface of the earth. In this connection it is to be noted that the potentials involved in wireless telegraphy are very large compared to those used in any of the other commercial applications of electricity, whereas the currents employed are in general relatively small compared to those which occur in some of the other applications of electricity, and furthermore, it must be remembered that in order to seriously disturb the potential of the earth at a given point, it is necessary to discharge into it an excessively large current as measured by these standards. It follows, therefore, that though the imperfect conductivity of the earth's surface may make it necessary to slightly modify the Hertz analysis, in order that it may strictly apply to the elevated conductor oscillator, yet such modification must result in an extremely minute connection, so long as the plane of the earth's surface is not seriously irregular in the immediate neighborhood of the elevated conductor.

Applicant sends herewith a sheet containing a lithographic fac simile of Fig.12 of the drawings, from which it was requested in a former communication that a certain portion be erased. The erasure desired is represented upon the fac simile in red ink.

Respectfully,

Alex. P. Browne Jr.

Att'y for Applicant.

2566

Serial No. 4505 Paper No. 13

Amendt E

Filed June 19 1902

IN THE UNITED STATES PATENT OFFICE.

--o--

Application of John Stone Stone,)
Method of Selective Electric Signaling,)
Filed Feb. 8, 1900, Ser. No. 4,505)

--o--

Hon. Commissioner of Patents.

Sir:-

The various claims heretofore made in this case, having been made at different times, and consequently being deemed lacking in harmony of nomenclature, it is considered desirable to cancel them and substitute others in their place, these latter differing only in phraseology. It has further been deemed desirable to add certain claims. Accordingly, applicant amends by canceling all the present claims and substituting the following:

18 "1. The method of developing free or unguided simple harmonic electro-magnetic waves of a definite frequency, which consists in producing forced simple harmonic electric vibrations of the same frequency in an elevated conductor.

E [illegible] The method of absorbing the energy of free [illegible] simple harmonic electro-magnetic signal waves of [illegible] of like waves [illegible] which consists in associating with [illegible] the frequency of [illegible] to be absorbed.

[illegible] The method of distributing the energy of free

or unguided electro-magnetic waves which consists in independently developing forced simple harmonic electric vibrations of different frequencies in an elevated conductor and receiving the several energies of the resulting electro-magnetic waves of different frequencies, each to the exclusion of the rest, in a separate electric translating device.

4. The method of distributing the energy of free or unguided electro-magnetic waves which consists in independently developing a number of forced simple harmonic electric vibrations of different frequencies in an elevated conductor and receiving the several energies of the resulting electro-magnetic waves, of different frequencies, each to the exclusion of the rest, in a separate circuit resonant to the same frequency as that of the waves, the energy of which is to be absorbed therein.

5. The method of distributing the energy of free or unguided electro-magnetic waves which consists in developing forced simple harmonic electric vibrations of different frequencies, each in a different elevated conductor, and receiving the several energies of the resulting electro-magnetic waves of different frequencies, each to the exclusion of the rest, in a separate electric translating device.

6. The method of distributing the energy of free or unguided electro-magnetic waves which consists in developing a number of forced simple harmonic electric vibrations of different frequencies, each in a different elevated conductor and receiving the several energies of the resulting electro-

E'

magnetic waves of different frequencies, each to the exclusion of the rest, in a separate resonant circuit attuned to the same frequency as that of the waves, the energy of which is to be absorbed therein.

7. The method of rendering a circuit resonant to given high frequency, which consists in balancing the reactance of an air condenser by the reactance of a coil, the amplitude of whose potential energy is small compared to the amplitude of its kinetic energy when it is supporting a current of said given high frequency.

8. The method of constructing a coil to be used in a circuit to be made resonant to a given high frequency which consists in so proportioning [illegible] that the amplitude of its potential energy shall be small compared to the amplitude of its kinetic energy when supporting a current of given high frequency.

9. The method of developing free or undamped simple harmonic electro-magnetic signal waves, which consists in discharging a condenser through a closed circuit [illegible] inductance adapted to produce under such conditions simple harmonic vibrations, and impressing the electrical vibrations so produced upon an open circuit or elevated conductor substantially as described.

10. The method of developing free or undamped simple harmonic electro-magnetic signal waves which consists in discharging a condenser through a closed circuit [illegible] inductance adapted to produce under such conditions [illegible] harmonic vibrations, impressing these vibrations [illegible]

circuit or group thereof resonant to the frequency of these vibrations, and impressing the resulting electrical vibrations upon an open circuit or elevated conductor.

11. The method of selectively receiving the energy of free or unguided simple harmonic electro-magnetic signal waves of different frequencies, each to the exclusion of the rest which consists in receiving the same in an elevated conductor and translating or conveying the several energies of the resulting electrical oscillations, each to a separate circuit associated with said elevated conductor, and resonant to the frequency of the electro-magnetic waves, the energy of which it is to receive.

12. The method of selectively receiving the energy of simple harmonic electro-magnetic signal waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in an elevated conductor and translating or conveying the several energies of the resulting electrical oscillations, each to a separate group of resonant circuits associated with said elevated conductor and resonant to the frequency of the electro-magnetic waves the energy of which it is to receive.

E'

13. [illegible] of selectively receiving the energy [illegible] harmonic electro-magnetic signal waves of [illegible], [illegible] exclusion of the rest, which consists in [illegible] in a plurality of [illegible] conductors, thereby developing in each elevated conductor [illegible] oscillations corresponding in frequency to [illegible] electro-magnetic waves [illegible] and in translating

or conveying from each elevated conductor to an associated circuit the energy of the particular electrical oscillations to the frequency of which said associated circuit is made resonant.

14. The method of selectively receiving the energy of simple harmonic electro-magnetic signal waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in a plurality of elevated conductors, thereby developing in each elevated conductor electrical oscillations corresponding in frequency to the electro-magnetic waves received [illegible] and in [illegible] conveying from each elevated conductor to a group of resonant circuits associated therewith the energy of the particular electrical oscillations to the frequency of which said group of associated circuits is resonant.

15. The method of absorbing the energy of free or unguided simple harmonic electro-magnetic signal waves of one frequency to the exclusion of the energy of like waves of different frequencies which consists in associating with an [illegible] frequency of the wave [illegible] which is to be absorbed.

20

16. The method of receiving the energy of simple harmonic electro-magnetic signal waves, which consists in receiving the same in an elevated conductor and [illegible] conveying the energy of the resulting electrical oscillations to an electrical [illegible] device [illegible] minals of [illegible] sociated [illegible]

frequency of the electro-magnetic waves.

17. The method of distributing the energy of free or unguided electro-magnetic waves, which consists in independently developing a number of forced simple harmonic electric vibrations of different frequencies in an elevated conductor and receiving the several energies of the resulting electro-magnetic waves of different frequencies, each to the exclusion of the rest, in a group of circuits resonant to the same frequency as that of the waves the energy of which is to be absorbed therein.

18. The method of distributing the energy of free or unguided electro-magnetic waves, which consists in developing a number of forced simple harmonic electric vibrations of different frequencies each in a different elevated conductor, and receiving the several energies of the resulting electro-magnetic waves of different frequencies, each to the exclusion of the rest, in a separate group of circuits resonant to the same frequency as that of the waves the energy of which is to be absorbed.

19. The method of developing free or unguided simple harmonic electro-magnetic signal waves, which consists in disturbing the electrical equilibrium of a circuit containing a condenser, and a coil having inductance adapted to produce under such conditions simple harmonic vibrations, impressing the electrical vibrations so produced upon an [illegible] or elevated conductor [illegible] described

[illegible]

[illegible]

4565 - F2

in disturbing the electrical equilibrium of a circuit comprising a condenser and a coil having inductance adapted to produce under such conditions simple harmonic vibrations, impressing these vibrations on a resonant circuit or group thereof attuned to the frequency of these vibrations, and impressing the resulting electrical vibrations upon an [illegible] circuit or elevated conductor.

1. The method of receiving the energy of simple harmonic electro-magnetic signal waves, which consists in [illegible] the same in an elevated conductor and translating [illegible] the energy of the resulting electrical oscillations [illegible] an electrical translating device forming one of the [illegible] resonant circuit associated with said elevated [illegible]ctor and resonant to the frequency of the electro-[illegible] waves.

2. [illegible] method of developing free or [illegible] [illegible]monic electro-magnetic signal waves or radiations, [illegible] in disturbing the electrical equilibrium of a [illegible] oscillating circuit [illegible] possessing sufficient auxiliary inductance to [illegible] of the [illegible] elevated conductor.

23. The method of developing free or [illegible] simple harmonic electro-magnetic signal waves or radiations, which consists in disturbing the electrical equilibrium of a closed oscillating circuit [illegible] resonant circuits associated with an [illegible] [illegible]

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swamp the effect of the mutual inductance between it and the other circuits of the group and between it and the elevated conductor.

24. The method of developing free or unguided simple harmonic electro-magnetic signal waves or radiations, of different frequencies independently in a single elevated conductor, which consists in disturbing the electrical equilibrium of closed oscillating circuits associated with said elevated conductor, each being attuned to a different of the frequencies to be developed, and each of the oscillating circuits having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the other oscillating circuits and the said elevated conductor.

25. The method of receiving the energy of simple harmonic electro-magnetic waves of a given frequency, to the exclusion of like waves of different frequencies, which consists in receiving the same in an elevated conductor and conveying the energy of the resulting electrical oscillations to a circuit associated with the elevated electrical conductor made resonant to the frequency of the electro-magnetic waves the energy of which is to be received by a condenser and an auxiliary inductance coil whose inductance is sufficient to swamp the effect of the mutual inductance between the associated circuit and the elevated conductor.

26. The method of selectively receiving the energy of simple harmonic electro-magnetic signal waves of one frequency, to the exclusion of like waves of different frequencies, which consists in receiving the same in an elevated

conductor and translating or conveying the energies of the resulting electrical oscillations each to a separate circuit associated with said elevated conductor, each resonant to the frequency of the electro-magnetic waves, the energy of which is to be received, and each having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the other associated circuits and between it and the elevated conductor.

22 27. The method of developing simple harmonic, electro-magnetic, signal waves or radiations of a given frequency, which consists in impressing upon a metallically continuous vertical oscillator forced simple harmonic electrical oscillations of the same frequency.

6 28. The method of simultaneously developing simple harmonic, electro-magnetic, signal waves or radiations of different frequencies, which consists in independently impressing upon a metallically continuous vertical oscillator forced, simple harmonic, electrical oscillations of the same frequencies.

29. The method of absorbing the energy of free or unguided, simple harmonic, electro-magnetic signal waves of one frequency, the exclusion of the energy of like waves of different frequency, which consists in associating with an elevated conductor a circuit resonant to the frequency of the waves, the energy of which is to be absorbed, and having sufficient auxiliary ~~induction~~ inductance to swamp the effect of the mutual inductance between it and the elevated conductor.

30. The method of distributing the energy of free or unguided, electro-magnetic waves, which consists in independently developing a number of forced, simple harmonic electric vibrations of different frequencies in an elevated conductor, and receiving the several energies of the resulting electro-magnetic waves of different frequencies, each to the exclusion of the rest in a separate circuit resonant to the same frequency as that of the waves, the energy of which is to be absorbed, and ~~having each~~ having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all of the circuits with which it is associated. ~~each of the other circuits, and between it and the elevated conductor.~~

31. The method of distributing the energy of free or unguided, electro-magnetic waves, which consists in developing a number of forced, simple harmonic, electric vibrations of different frequencies, each in a different elevated conductor, and receiving the several energies of the resulting electro-magnetic waves of different frequencies, each to the exclusion of the rest, in a separate resonant circuit attuned to the same frequency as that of the waves, the energy of which is to be absorbed therein, and having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated. ~~the other resonant circuits and between it and the elevated conductor.~~

32. The method of developing free or unguided, simple harmonic, electro-magnetic signal waves, which consists in discharging a condenser through a closed circuit having inductance adapted to produce under such conditions simple

harmonic vibrations and sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and an elevated conductor with which it is associated, and impressing the electrical vibrations so produced upon the said elevated conductor.

33 33. The method of developing free or unguided, simple harmonic, electro-magnetic, signal waves, which consists in discharging a condenser through a closed circuit having inductance adapted to produce under such conditions simple harmonic vibrations, impressing these vibrations on a resonant circuit or group thereof resonant to the frequency of these vibrations, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated, and impressing the resulting electrical vibrations upon an open circuit or elevated conductor.

34. The method of selectively receiving the energy of free or unguided, simple harmonic, electro-magnetic, signal waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in an elevated conductor and translating or conveying the several energies of the resulting electrical oscillations, each to a separate circuit associated with said elevated conductor, and resonant to the frequency of the electro-magnetic waves, the energy of which it is to receive, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

35. The method of selectively receiving the energy of simple harmonic, electro-magnetic, signal waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in an elevated conductor and [illegible] translating or conveying the several energies of the resulting electrical oscillations, each to a separate group of resonant circuits associated with said elevated conductor and resonant to the frequency of the electro-magnetic waves, the energy of which it is to receive, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

36. The method of selectively receiving [illegible] of free or unguided. simple harmonic, electro-magne[illegible] waves of different frequencies, each to the exclusion of the rest, which consists in receiving the same in a plurality of elevated conductors, thereby developing in each elevated conductor electrical oscillations corresponding in frequency to the electro-magnetic waves received by it and in translating or conveying from each elevated conductor to an associated circuit the energy of the particular electrical oscillations to the frequency of which said associated circuit is made resonant, each of said circuits having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the elevated conductor and all circuits with which it is associated.

37. The method of selectively receiving the energy of simple harmonic, electro-magnetic, signal waves of differ-

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ent frequencies, each to the exclusion of the rest, which consists in receiving the same in a plurality of elevated conductors, thereby developing in each elevated conductor electrical oscillations corresponding in frequency to the electro-magnetic waves received by it and in translating or converting from each elevated conductor to a group of resonant circuits associated therewith the energy of the particular electrical oscillations to the frequency of which said group of associated circuits is resonant, [illegible] said [illegible] having sufficient auxiliary inductance to [illegible] the [illegible] mutual inductance between [illegible] and all circuits with which it is associated.

38. The method of [illegible] the energy of [illegible] unguided, simple harmonic, electro-magnetic, signal waves of one frequency to the exclusion of the energy of like waves of different frequencies, which consists in associating with an elevated conductor a group of circuits, each resonant to the frequency of the waves [illegible] sorbed, each circuit having [illegible] to swamp the effect of the [illegible] inductance [illegible] all circuits with which it is associated.

39. The method of [illegible] simple harmonic, electro-magnetic signal waves, which consists in receiving the same in an elevated conductor [illegible] or conveying the energy of the resulting electrical oscillations to an electrical translating device [illegible] the terminals of one of the elements of a resonant circuit associated with said elevated conductor and resonant to the

frequency of the electro-magnetic waves, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

40. The method of distributing the energy of free or unguided electro-magnetic waves, which consists in independently developing a number of forced, simple harmonic, electric vibrations of different frequencies in an elevated conductor and receiving the several energies of the resulting electro-magnetic waves of different frequencies, each to the exclusion of the rest, in a group of circuits resonant to the same frequency as that of the waves, the energy of which is to be absorbed therein, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

25 41. The method of distributing the energy of free or unguided electro-magnetic waves, which consists in developing a number of forced, simple harmonic, electric vibrations of different frequencies, each in a different elevated conductor, and receiving the several energies of the resulting electro-magnetic waves of different frequencies, each to the exclusion of the rest, in a separate group of circuits resonant to the same frequency as that of the waves the energy of which is to be absorbed, each of said circuits having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and the elevated conductor and all circuits with which it is associated.

42. The method of developing free or unguided,

simple harmonic, electro-magnetic signal waves, which consists in disturbing the electrical equilibrium of a circuit comprising a condenser, and a coil having inductance adapted to produce under such conditions simple harmonic vibrations, and impressing the electrical vibrations so produced upon an elevated conductor, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

43. The method of developing free or unguided, simple harmonic, electro-magnetic signal waves, which consists in disturbing the electrical equilibrium of a circuit comprising a condenser and a coil having inductance adapted to produce under such conditions simple harmonic vibrations, impressing these vibrations on a resonant circuit or group thereof attuned to the frequency of these vibrations, and impressing the resulting electrical vibrations upon an elevated conductor each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

44. The method of receiving the energy of simple harmonic, electro-magnetic signal waves, which consists in receiving the same in an elevated conductor and translating or conveying the energy of the resulting electrical oscillations to an electrical translating device forming one of the elements of a resonant circuit associated with said elevated conductor and resonant to the frequency of the electro-magnetic waves, each circuit having sufficient auxiliary inductance to swamp the effect of the mutual inductance between it and all circuits with which it is associated.

Respectfully submitted

Alex. S. Browne,

atty for appellt

4.00

Washn D.C.

June 18 190

-506- Paper 14

Amendt F

Filed June 19 1902

IN THE UNITED STATES PATENT OFFICE.

Room No. 91. Serial No. 4505.

Application of John Stone Stone,

For Patent for Improvement in Method of Selective Electric Signaling.

Filed Feb. 8, 1900.

Hon. Commissioner of Patents,

Washington, D.C.

Sir:-

Applicant observes that in his amendment of May 28, 1902 he so amended his case as to make it read "It is to be here noted that the above described methods of simultaneously transmitting and receiving space telegraph messages by a common elevated conductor are not described as the preferred methods", etc.

As this passage is not in his judgment sufficiently explained in the text of his application, he amends by inserting after the word "methods", line ~~9~~ 7, page 2, amendment of April 8, 1902, the following: "Since the branch circuits M M, in Figs. 16 and 17 are not in themselves selective, and since the elevated conductors in Figs. 13 and 14 contain a number of induction coils in series, not essential to the operation of any one of the stations singly,"

Applicant amends by introducing after the paragraph to which the foregoing amendment applies, the following paragraph: "The branch circuits M M, of Fig. 17 are not selective since they contain but one element of a tuned circuit, viz.,

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the inductance of M and M_1. Vibratory currents of whatever frequently they may be, communicated by the vertical wire to these circuits, will divide amongst them in simple inverse proportion to their electro-magnetic impedances and are not selective except for a slight reaction due to the associated circuits C' M' L' and C'_1 M_1 L'_1. These reactions, so far from tending to make the branches selective to the frequencies to which their associated circuits are intended to respond, will in fact, cause them to oppose more strongly currents of these frequencies than those to which the associated circuits are not attuned. Again it is obvious that the inductance of the coil M in Fig. 13 is merely an additional impedance in the elevated conductor, which, to say the least, cannot assist in the development of vibrations in the elevated conductor impressed by circuit C'_1 M'_1 L'_1 M_1. The same is obviously true of the coil M_1 in the elevated conductor with reference to the operation of the circuit C' M' L'. Now passing to the transmitting station shown at Fig. 16, it is obvious that the vibrations communicated by the circuit C' M' L' to the elevated conductor V are subject to a shunt due to the coil M_1 in the other branch of the elevated conductor, and conversely the vibrations developed in the elevated conductor by the associated circuit C', M', L', are subject to a shunt due to the coil M in the other branch of the elevated conductor. Finally, the coil M in the elevated conductor in Fig. 14 can at best only present an impedance to the waves intended to be received by the circuit C', M', L', and conversely the coil M_1 in the elevated conductor can at best only present an impedance to the vibrations intended to be received by the circuit C' M' L'."

Amend the specification by inserting at the end thereof, and immediately before the claims, the following:

"In this specification I have described the development of free or unguided electro-magnetic signal waves of a given frequency, by employing in association with an elevated conductor, a circuit such as to produce therein forced simple harmonic electric vibrations of the frequency desired. I have also described a method of receiving or absorbing the energy of free or unguided simple harmonic electro-magnetic waves of one frequency to the exclusion of waves of a different frequency by associating with an elevated conductor a circuit made resonant to the frequency of the waves whose energy is to be absorbed. The circuit whereby forced simple harmonic electric vibrations are produced in the elevated conductor I have shown as a circuit containing a condenser and a self-induction coil so proportioned as to make the natural vibrations of a frequency which is the frequency of the vibrations to be forced or impressed in an elevated conductor. The circuit whereby the energy of the electro-magnetic waves of one frequency is absorbed to the exclusion of that of waves of other frequencies is in like manner a circuit containing a condenser and a self-induction coil so proportioned as to make the circuit resonant to a frequency which is the frequency of the waves, the energy of which is to be received. Both of the circuits I have spoken of are tuned circuits, and they may be conveniently distinguished with reference to their respective functions by denominating the circuit employed in the development of the vibrations as an oscillating or sonorous circuit, and by denominating the circuit employed in the reception or absorption of the vibrations as a resonant

circuit. I prefer to make this discrimination in nomenclature for the reason that while both the circuits are resonant circuits yet functionally only that one employed for receiving or absorbing is accurately so described.

Except for this distinction in function it is well to note that all oscillating or sonorous circuits are resonant circuits but only such resonant circuits as have their resistance less than the square foot of the ratio of four times their inductance by their capacity are oscillating or sonorous circuits.

Also throughout this specification I have described the electrical oscillations or vibrations and the free or unguided electro-magnetic waves or radiations as simple harmonic. [redacted] It is the object of my present invention to approach as nearly as possible to perfect simple harmonic wave, and such object is attained to within such a degree of precision as to preclude any interference with the operation of the system by any possible departure that may exist in the wave from the absolute simple harmonic form. My reason for confining the description of the electrical oscillations or vibrations and the electro-magnetic waves or vibrations to the simple harmonic type is that, in the operation of the system, only the simple harmonic components are effective in carrying out the object of the invention. Though it is impossible to prevent the presence of ~~the~~ minute over-tones accompanying these simple harmonic waves, such over tones not only do not contribute to the useful operation of the system, but may in fact become obstacles to such useful and complete operation, unless their amplitude be excessively small as is the case in the present invention.

It is for this reason that I have taken every precaution to approximate as closely as may be to the true or absolute simple harmonic wave-form, thereby reducing to a minimum the over tones which cause a departure from the true sine wave.

Specifically, though it may be possible to employ the purposes of multiple and selective wireless telegraphy electric vibrations and radiations departing considerably from the simple harmonic type by employing at the receiving end circuits selective to the fundamental of such vibrations and radiations, yet it will only be through the selective reception of that simple harmonic component of the vibrations or radiations which is their fundamental that the system will be operative. The other simple harmonic components of the vibrations or radiations add nothing to the operation of the system.

Moreover, if such over tones exist in the waves emenating from a transmitting station, their presence will preclude the possibility of placing receiving stations in the immediate neighborhood of such transmitting station for the reception of signal waves of frequencies corresponding to the frequencies of such over tunes."

Amend the specification by inserting at line 15, page 15 thereof, the following:

The mathamatical expression for the frequency to which a circuit is resonant when it is isolated from all other circuits i.e. has but a single degree of freedom is well known and may be stated as follows:-

$$n = \frac{1}{2\pi\sqrt{C_1 L_1}}$$ from which

$$L_1 = \frac{1}{C_1 p^2}.$$

where n is the frequency, C_1 is the capacity, L_1 is the inductance and p is the periodicity which equals $2\pi n$.

In the case of a circuit of two degrees of freedom, however, in order to make the component circuits each responsive to the same frequency as when isolated, in other words to overcome the modifying effect of the mutual inductance of each circuit upon the other, it necessary to consider, in the case of inductive relation, the expression:-

$$\frac{1}{C_1 p^2} = L_1 - \frac{M_{12}^2 p\left(L_2 p - \frac{1}{C_2 p}\right)}{R_2^2 + \left(L_2 p - \frac{1}{C_2 p}\right)^2},$$

where C_1 L_1 are the capacity and inductance of the first ~~of the first circuit~~ circuit C_2, L_2, R_2 are the capacity, inductance and resistance, respectively of the second circuit and M_{12} is the mutual inductance of the circuits.

From these expressions careful consideration will show that the effective inductance of the first circuit has been modified by its inductive relation with the second circuit and it is:-

$$L_1' = L_1 - \frac{M_{12}^2 p\left(L_2 p - \frac{1}{C_2 p}\right)}{R_2^2 + \left(L_2 p - \frac{1}{C_2 p}\right)^2}$$

Similarly we have to consider the expression:-

$$\frac{1}{C_2 p^2} = L_2 - \frac{M_{12}^2 p\left(L_1 p - \frac{1}{C_1 p}\right)}{R_1^2 + \left(L_1 p - \frac{1}{C_1 p}\right)^2},$$

from which it will be seen that the effective inductance of the second circuit has been modified by its inductive relation with the first circuit and is:

$$L'_2 = L_2 - \frac{M^2 p\,(L_1 p - \frac{1}{C_1 p})}{R_1^2 + (L_1 p - \frac{1}{C_1 p})^2}$$

These two inductances L'_1 and L'_2 are the apparent inductances which each of these circuits would have if acting as the primary to induce simple harmonic vibrations of frequency n in the other.

It is therefore necessary in order to overcome the modifying effect of the mutual inductance on either circuit to add to that circuit an auxiliary inductance coil of inductance large compared to the term of the form :-

$$\frac{M^2 p\,(L p - \frac{1}{C p})}{R^2 + (L p - \frac{1}{C p})^2}$$

, or at least so large that when added to the natural inductance of the circuit the sum of their inductances is very large compared to the said term.

Respectfully,

Alex P. Browne,
atty for applt

Washn DC
June 18. 02

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Serial No, 4505— Paper No, 13—

Amendt ?

Filed June 19 1902

IN THE UNITED STATES PATENT OFFICE.

--o--

Application of John Stone Stone

Ser. No. 4,5[illegible], filed Feb 8 1900

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Hon. Commissioner of Patents,

Sir:-

[illegible] above-entitled case is hereby amended as follows

[illegible] the end of the specification, and immediately

before the claims, insert the following:

"Whereas in the present specification I have used the term "elevated conductor" to describe the source of radiation of electro-magnetic waves developed by [illegible] electrical oscillations impressed thereon, [illegible] this expression [illegible] the term [illegible] systems [illegible] that term is employed [illegible] a wire or other [illegible] of course [illegible] specification relates, [illegible] The [illegible], [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

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essential to the theory of the propagation of electrical and magnetic force, radiant light and radiant heat."

Respectfully submitted,

Alex P Browne
atty for applts

Washington, D. C.,

June 19, 1902.

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Division. 2—181. Serial No. 4,2[illegible]

Communications should be addressed to "Commissioner of Patents, Washington, D. C."

DEPARTMENT OF THE INTERIOR.

U. S. Patent Office,

Washington, D. C., [illegible] 20, 190[illegible]

[illegible]

SIR,—Your APPLICATION for a patent for an IMPROVEMENT IN

[illegible]

Filed [illegible] has been examined and ALLOWED.

The final fee, Twenty Dollars, must be paid, and the Letters Patent bear date as of a day not later than SIX MONTHS from the time of this present notice of allowance.

If the final fee is not paid within that period the patent will be withheld, and your only relief will be by a renewal of the application, with additional fees, under the provisions of Section 4897, Revised Statutes. The Office aims to deliver patents upon the day of their date, and on which their term begins to run; but to do this properly applicants will be expected to pay their final fees at least TWENTY DAYS prior to the conclusion of the six months allowed them by law. The printing, photolithographing, and engrossing of the several patent parts, preparatory to final signing and sealing, will consume the intervening time, and such work will not be done until after payment of the necessary fees.

When you send the final fee you will also send, DISTINCTLY AND PLAINLY WRITTEN, the name of the INVENTOR and TITLE OF INVENTION AS ABOVE GIVEN, DATE OF ALLOWANCE (which is the date of this circular), DATE OF FILING, and, if assigned, the NAMES OF THE ASSIGNEES.

If you desire to have the patent issue to ASSIGNEES, an assignment containing a REQUEST to that effect, together with the FEE for recording the same, must be filed in this Office on or before the date of payment of final fee.

Additional copies of Specifications and Drawings will be charged for at the following rates: Single Copies, unmounted, 5 cents each. The money should accompany the order.

Very respectfully,

F. I. Allen.

Commissioner of Patents.

IN REMITTING THE FINAL FEE GIVE THE SERIAL NUMBER AT THE HEAD OF THIS NOTICE.

If payment is made by check or draft, the credit allowed is subject to the collection of the same.

After allowance and prior to payment of the final fee, applicants should carefully scrutinize the description to see that their statements and language are correct, as mistakes not occurred through the fault of the office, and not affording legal grounds for reissues, will not be corrected after the delivery of the letters patent to the patentee or his agent.

37930

Department of the Interior,

U. S. PATENT OFFICE.

Washington, D. C. Nov. 5 , 1902

PETITION

Application of [illegible] J. Allen

Ser. No. [illegible]

Method of Selective Electric Signaling

[illegible] referred to the Examiner in charge of Division 16 for recommendation

whether he recommends [illegible] reasons therefor.

F. I. Allen.

Commissioner of Patents

Serial No. 4000 Paper No. 16

Amendt H (Rule 78)

Filed Nov. 4 1902

IN THE UNITED STATES PATENT OFFICE.

Room #91, Serial No. 4505.

Application of John Stone Stone,

For Patent for Method of Selective Electric Signaling.

Filed February 8,1900. Allowed June 26,1902.

31 State Street,
Boston,Mass. Nov. 3,1902.

Hon. Commissioner of Patents,

Washington, D.C.

Sir:-

It is respectfully requested that the following claim be entered in the above entitled application under Rule 78, without withdrawing the case from issue.

45. The method of absorbing the energy of free or unguided simple harmonic electro-magnetic signal waves of one frequency, to the exclusion of the energy of like waves of different frequency, which consist in receiving the same in an elevated conductor and translating or conveying the resulting electric vibrations to a circuit associated with said elevated conductor, and resonant to the frequency of the waves, the energy of which is to be received.

It is believed that this claim is patentable, and that it may be allowed without further search on the part of the Office.

Respectfully,

John Stone Stone

Applicant.

The claim is patentable and it is recommended that the amendment be entered under Rule 78 without withdrawing the case from issue. The final fee has not been paid.

Approved
GKW.

Nov. 1902

F. I. Allen actg

Wm A Kinnan
Examiner, Division XVI.

Two papers ~~350~~ 300

Communications should be addressed to
The Commissioner of Patents,
Washington, D. C.

M. A. W.

LETTER NO.

DEPARTMENT OF THE INTERIOR,
UNITED STATES PATENT OFFICE,
WASHINGTON, D. C.

Serial No. 4505 Paper No. 17
Notice of Commr's Decision

Dated November 6th, 1902.

In the matter of the
Application of
John S. Stone,
Method of Selective Electric
Signaling,
Filed February 8. 1900,
Ser. No. 4505.

Amendment.

Sir:

You are hereby informed that the recommendation of the Examiner, that the amendment be admitted under the provisions of Rule 78, has been approved by the Commissioner.

By direction of the Commissioner.

Very respectfully,

C. M. Drelan
Chief Clerk.

John S. Stone,

c/o Watson & Watson,

Washington, D. C.

100

2—327.

MEMORANDUM

OF

FEE PAID AT UNITED STATES PATENT OFFICE.

(Be careful to give correct Serial No.)

Serial No. 4505 , *190*

INVENTOR:

John Stone Stone

PATENT TO BE ISSUED TO

As per record

NAME OF INVENTION, AS ALLOWED:

Method of & App for Selective Electric Signaling

DATE OF PAYMENT:

Nov - 5-1902

FEE:

$20

DATE OF FILING:

Feb - 8-1900

DATE OF CIRCULAR OF ALLOWANCE:

June - 20-1902

The Commissioner of Patents will please apply the accompanying fee as indicated above.

Alex. P. Browne

Attorney.

SEND PATENT TO

Alex. P. Browne, Esq.
31 State St
Boston, Mass.

50

WATSON & WATSON
PATENT LAWYERS AND SOLICITORS,
WASHINGTON, D. C.
[illegible] F STREET

James [illegible] Watson
Robert Watson
John Watson, Jr.
Arthur [illegible]

WASHINGTON, D.C. [illegible], 1902

[illegible] Commissioner [illegible] Patents,
[illegible], D. C.

[illegible] :-

I [illegible] herewith [illegible] Watson & Watson for $[illegible] [illegible] final Government fee [illegible] Stone [illegible] Electric Signalling, [illegible],

Serial No. [illegible], filed Feb. [illegible], 1900; [illegible]
" " [illegible] " Jan. [illegible] " [illegible]
" " [illegible] " [illegible] " [illegible]

[illegible],

Alfred [illegible]
Atty. for [illegible]

[illegible]

3359

PRESIDENT
ALEXANDER P. BROWNE
VICE PRESIDENT
... WHICHER
... TREASURER
BRAINERD T. JUDKINS

STONE TELEGRAPH AND TELEPHONE CO.
OFFICE 31 STATE STREET
BOSTON MASS
LABORATORY 18 WESTERN AVENUE CAMBRIDGE
TELEPHONES 3394 MAIN BOSTON
AND 1048 CAMBRIDGE

PATENT COUNSEL
ALEXANDER P. BROWNE
ELECTRICAL ENGINEER
JOHN STONE STONE

Nov. 19,1903.

Hon. Commissioner of Patents,

Washington, D.C.

Sir:-

I herewith return Letters Patent No. 714,756,granted Dec.2,1902, to Louis E.Whicher,Alex.P.Browne and Brainerd T.Judkins on the application of John Stone Stone and now owned by the Stone Telegraph and Telephone Company,and request that a certificate of correction be annexed thereto under the provisions of Rule 170, in order to correct the following errors incurred through the fault of the office in printing the specification, to wit:-

In line 85,page 1, change the semi-colon(;) to a period(.) and change "but" to "But".

In line 91,page 1, change the period(.) to a comma(,) and change "It" to "it".

In line 109,page 5,change " $\frac{1}{C_1 p_2}$ " to $\frac{1}{C_1 p^2}$

In line 124,page 5, change the first member of the equation from " $\frac{1}{C_1 p_2}$ " to $\frac{1}{C_1 p^2}$

In line 91,page 10,change the dash(-) between the words "non-metallic" and "non-conducting" to a comma(,), cancel the dash (-) between the words "fact" and "dielectric"; and in line 92,page 10,insert a comma(,) between the words "dielectric" and "medium"; so that lines 91 and 92 will read,"non-metallic, non-conducting, in fact dielectric, medium" &c.

This certificate is requested so that the printed specification

will conform with the specification now on record in the archives of the Patent Office, and because, by reason of the changes in punctuation introduced by the printer, the meaning of certain parts of the specification has been completely changed.

Respectfully,

Alex P. Browne

Attorney for Stone,

[illegible]

Sec'y & Treas. Stone Tel.
& Tel.Co.

Browne, A. F. 2d

198161

It is directed that a certificate of correction be endorsed upon Letters Patent No. 714,756, making the changes requested, with the exception that the period in line 91, page 1, should be changed to a semicolon and not to a comma, to conform to the record of the case.

E. B. Moore
Acting Commissioner.

November [illegible], 1903.

3362

All communications should be addressed to
The Commissioner of Patents,
Washington, D. C.

LETTER No.

DEPARTMENT OF THE INTERIOR,
UNITED STATES PATENT OFFICE,
WASHINGTON, D. C.

In the matter of
Letters Patent No.714,756,
Issued December 2,1902,
John Stone Stone,
Methods of Selective Signaling,
Mr.Alex P.Browne,attorney.

REPORT of the CHIEF of the ISSUE and GAZETTE DIVISION.

The patent is returned calling attention to four departures in the printed specification from the punctuation of the original manuscript,and two errors in the algebraic formulas.

In the matter of punctuation:---

1st In line 85,page 1,the semicolon after the word "systems" should be changed to a period,and the following word "but" should commence with a capital B,making a new sentence,to accord with the copy.

2nd In line 91,page 1,the period after the word "neighborhood" should be changed to a semicolon,(not to a comma as he requests) and the following word "It" should commence with a small i,to conform to the record.

3rd In line 91,page 10,a comma should be substituted for the dash after the word "non-metallic" and the dash after the word "fact" should be stricken out to conform to the copy.

4th In line 92,page 10,a comma should be inserted after the word "dielectric."

In the matter of changed formula:

1st In lines 105-110,page 5,and 2nd In lines 120-125, same page,in the first member of the formula the printer used the inferior "I_2" instead of the superior I^2,as was evidently intended by the writer of the specification.

straight wire attached freely to the terminal of the coil. These motions are, of course, due to the impact of the molecules, and the irregularity in the distribution of the potential, owing to the roughness and dissymmetry of the wire or filament. With a perfectly symmetrical and polished wire such motions would probably not occur. That the motion is not likely to be due to others causes is evident from the fact that it is not of a definite direction, and that in a very highly exhausted globe it ceases altogether. The possibility of bringing a body to incandescence in an exhausted globe, or even when not at all enclosed, would seem to afford a possible way of obtaining light effects, which, in perfecting methods of producing rapidly alternating potentials, might be rendered available for useful purposes.

In employing a commercial coil, the production of very powerful brush effects is attended with considerable difficulties, for

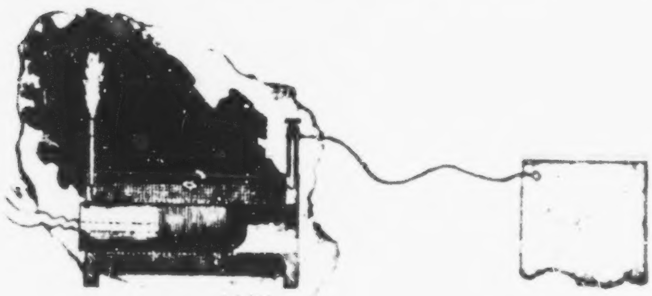


FIG. [illegible]

when these high frequencies and enormous potentials are used, the best insulation is apt to give way. Usually the coil is insulated well enough to stand the strain from convolution to convolution, since two double silk covered paraffined wires will withstand a pressure of several thousand volts; the difficulty lies principally in preventing the breaking through from the secondary to the primary, which is greatly facilitated by the streams issuing from the latter. In the coil, of course, the strain is greatest from section to section, but usually in a larger coil there are so many sections that the danger of a sudden discharge is not very great. No difficulty will generally be encountered in that direction, and besides, the liability of injuring the coil internally is very much reduced by the fact that the effect most likely to be produced is simply a gradual heating, which

by able pioneers. Many have been carried away by the enthusiasm and passion to discover, but in their zeal to reach results, some have been misled. Starting with the idea of producing electro-magnetic waves, they turned their attention, perhaps, too much to the study of electro-magnetic effects, and neglected the study of electrostatic phenomena. Naturally, nearly every investigator availed himself of an apparatus similar to that used in earlier experiments. But in those forms of apparatus, while the electro-magnetic inductive effects are enormous, the electrostatic effects are excessively small.

In the Hertz experiments, for instance, a high tension induction coil is short circuited by an arc, the resistance of which is very small, the smaller, the more capacity is attached to the terminals; and the difference of potential at these is enormously diminished. On the other hand, when the discharge is not passing between the terminals, the static effects may be considerable, but only qualitatively so, not quantitatively, since their rise and fall is very sudden, and since their frequency is small. In neither case, therefore, are powerful electrostatic effects perceivable. Similar conditions exist when, as in some interesting experiments of Dr. Lodge, Leyden jars are discharged disruptively. It has been thought—and I believe asserted—that in such cases most of the energy is radiated into space. In the light of the experiments which I have described above, it will now not be thought so. I feel safe in asserting that in such cases most of the energy is partly taken up and converted into heat in the arc of the discharge and in the conducting and insulating material of the jar, some energy being, of course, given off by electrification of the air; but the amount of the directly radiated energy is very small.

When a high tension induction coil, operated by currents alternating only 20,000 times a second, has its terminals closed through even a very small jar, practically all the energy passes through the dielectric of the jar, which is heated, and the electrostatic effects manifest themselves outwardly only to a very weak degree. Now the external circuit of a Leyden jar, that is, the arc and the connections of the coatings, may be looked upon as a circuit generating alternating currents of excessively high frequency and fairly high potential, which is closed through the coatings and the dielectric between them, and from the above it is evident that the external electrostatic effects must be very

[illegible] connected to one terminal [illegible] may be provided.

The ideal way of lighting [illegible] would, however, be

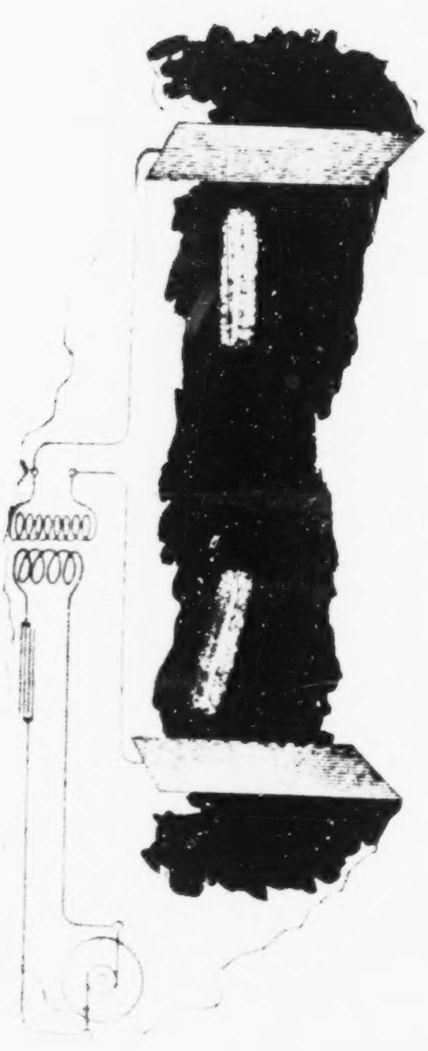


Fig. [illegible]

to produce such a condition [illegible] that an illuminating [illegible] could be moved and put anywhere, and that it is lighted, [illegible] ter where it is put and [illegible] being electrically connected [illegible]

[illegible]. I have been able to produce such a condition in a room by the use of a powerful rapidly alternating electrostatic field. For this purpose I suspend a sheet of metal a distance from the ceiling on insulating cords and connect it to one terminal of the induction coil, the other terminal being preferably connected to the ground. Or else I suspend two sheets as illustrated in Fig. 125, each sheet being connected with one of the terminals of the coil, and their size being carefully determined. An exhausted tube may then be carried in the hand anywhere between the sheets or placed anywhere, even a certain distance beyond them; it remains always luminous.

In such an electrostatic field interesting phenomena may be observed, especially if the alternations are kept low and the potentials excessively high. In addition to the luminous phenomena mentioned, one may observe that any insulated conductor gives sparks when the hand or another object is approached to it, and the sparks may often be powerful. When a large conducting object is fastened on an insulating support, and the hand approached to it, a vibration, due to the rhythmical motion of the air molecules is felt, and luminous streams may be perceived when the hand is held near a pointed projection. When a telephone receiver is made to touch with one or both of its terminals an insulated conductor of some size, the telephone emits a loud sound; it also emits a sound when a length of wire is attached to one or both terminals, and with very powerful fields a sound may be perceived even without any wire.

How far this principle is capable of practical application, the future will tell. It might be thought that electrostatic effects are unsuited for such action at a distance. Electromagnetic inductive effects, if available for the production of light, might be thought better suited. It is true the electrostatic effects diminish nearly with the cube of the distance from the coil, whereas the electromagnetic inductive effects diminish simply with the distance. But when we establish an electrostatic field of force, the condition is very different, for then, instead of the differential effect of both the terminals, we get their conjoint effect. Besides, I would call attention to the effect, that in an alternating electrostatic field, a conductor, such as an exhausted tube, for instance, tends to take up most of the energy, whereas in an electromagnetic alternating field the conductor tends to take up the least energy, the waves being reflected with but little loss.

This [illegible] the exhibition [illegible] of very large [illegible] and of high [illegible] [illegible] the [illegible] the tube at a distance; but even with the powerful inductive effects producible by Leyden jar discharges, the tube could not be excited unless at a very small distance, although some judgment was used as to the dimensions of the coil. I have also found that even the most powerful Leyden jar discharges are capable of exciting only feeble luminous effects in a closed exhausted tube, and even these effects upon thorough examination I have been forced to consider of an electrostatic nature.

How then can we hope to produce the required effects at a distance by means of electromagnetic action, when even in the closest proximity to the source of disturbance, under the most advantageous conditions, we can excite but faint luminosity? It is true that when acting at a distance we have the resonance to help us out. We can connect an exhausted tube, or whatever the illuminating device may be, with an insulated system of the proper capacity, and so it may be possible to increase the effect qualitatively, and only qualitatively, for we would not get *more* energy through the device. So we may, by resonance effect, obtain the required electromotive force in an exhausted tube, and excite faint luminous effects, but we cannot get enough energy to render the light practically available, and a simple calculation, based on experimental results, shows that even if all the energy which a tube would receive at a certain distance from the source should be wholly converted into light, it would hardly satisfy the practical requirements. Hence the necessity of directing, by means of a conducting circuit, the energy to the place of transformation. But in so doing we cannot very sensibly depart from present methods, and all we could do would be to improve the apparatus.

From these considerations it would seem that if this ideal way of lighting is to be rendered practicable it will be only by the use of electrostatic effects. In such a case the most powerful electrostatic inductive effects are needed; the apparatus employed must, therefore, be capable of producing high electrostatic potentials changing in value with extreme rapidity. High frequencies are especially wanted, for practical considerations make it desirable to keep down the potential. By the employment of machines,

is, generally speaking, of any mechanical apparatus, but low frequencies can be reached; recourse must, therefore, be had to some other means. The discharge of a condenser affords us a means of obtaining frequencies by far higher than are obtainable mechanically, and I have accordingly employed condensers in the experiments to the above end.

When the terminals of a high tension induction coil, Fig. 126, are connected to a Leyden jar, and the latter is discharging disruptively into a circuit, we may look upon the arc playing between the knobs as being a source of alternating, or generally speaking, undulating currents, and then we have to deal with the familiar system of a generator of such currents, a circuit connected to it, and a condenser bridging the circuit. The condenser in such case is a veritable transformer, and since the frequency is excessive, almost any ratio in the strength of the currents in both the branches may be obtained. In reality the analogy is not quite complete, for in the disruptive discharge we have most generally a fundamental instantaneous variation of comparatively low frequency, and a superimposed harmonic vibration, and the laws governing the flow of currents are not the same for both.

In converting in this manner, the ratio of conversion should not be too great, for the loss in the arc between the knobs increases with the square of the current, and if the jar be discharged through very thick and short conductors, with the view of obtaining a very rapid oscillation, a very considerable portion of the energy stored is lost. On the other hand, too small ratios are not practicable for many obvious reasons.

As the converted currents flow in a practically closed circuit, the electrostatic effects are necessarily small, and I therefore convert them into currents or effects of the required character. I have effected such conversions in several ways. The preferred plan of connections is illustrated in Fig. 127. The manner of operating renders it easy to obtain by means of a small and inexpensive apparatus enormous differences of potential which have been usually obtained by means of large and expensive coils. For this it is only necessary to take an ordinary small coil, adjust to it a condenser and discharging circuit, forming the primary of an auxiliary small coil, and convert upward. As the inductive effect of the primary currents is excessively great, the second coil need have comparatively but very few turns. By properly adjusting the elements, remarkable results may be secured.

In endeavoring [illegible] this manner, I [illegible] difficulties which I have been gradually overcoming, but I am not as yet prepared to dwell upon my experiences in this direction.

I believe that the disruptive discharge of a condenser will play an important part in the future, for it offers vast possibilities, not only in the way of producing light in a more efficient manner and in the line indicated by theory, but also in many other respects.

For years the efforts of inventors have been directed towards obtaining electrical energy from heat by means of the thermopile. It might seem invidious to remark that but few know what is the real trouble with the thermopile. It is not the inefficiency or small output—though these are great drawbacks—but the fact that the thermopile has its phylloxera, that is, that by constant use it is deteriorated, which has thus far prevented its

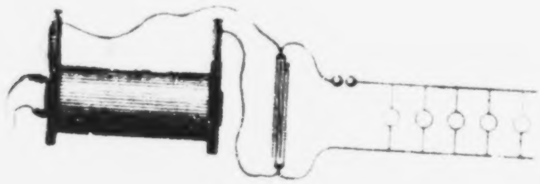


FIG. 126

introduction on an industrial scale. Now that all modern research seems to point with certainty to the use of electricity of excessively high tension, the question must present itself to many whether it is not possible to obtain in a practicable manner this form of energy from heat. We have been used to look upon an electrostatic machine as a plaything, and somehow we couple with it the idea of the inefficient and impractical. But now we must think differently, for now we know that everywhere we have to deal with the same forces, and that it is a mere question of inventing proper methods or apparatus for rendering them available.

In the present systems of electrical distribution, the employment of the iron with its wonderful magnetic properties allows us to reduce considerably the size of the apparatus; but, in spite of this, it is still very cumbersome. The more we progress in the study of electric and magnetic phenomena, the more we be-

come convinced that the present methods will be short-lived. For the production of light, at least, such heavy machinery would seem to be unnecessary. The energy required is very small, and if light can be obtained as efficiently as, theoretically, it appears possible, the apparatus need have but a very small output. There being a strong probability that the illuminating methods of the future will involve the use of very high potentials, it seems very desirable to perfect a contrivance capable of converting the energy of heat into energy of the requisite form. Nothing to speak of has been done towards this end, for the thought that electricity of some 50,000 or 100,000 volts pressure or more, even if obtained, would be unavailable for practical purposes, has deterred inventors from working in this direction.

In Fig. 126 a plan of connections is shown for converting currents of high, into currents of low, tension by means of the disruptive discharge of a condenser. This plan has been used by

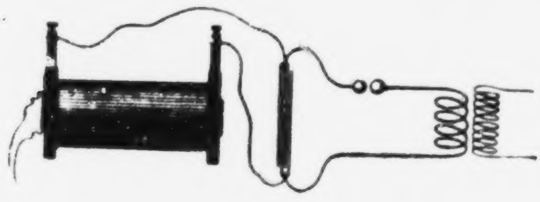


FIG. 127.

me frequently for operating a few incandescent lamps required in the laboratory. Some difficulties have been encountered in the arc of the discharge which I have been able to overcome to a great extent; besides this, and the adjustment necessary for the proper working, no other difficulties have been met with, and it was easy to operate ordinary lamps, and even motors, in this manner. The line being connected to the ground, all the wires could be handled with perfect impunity, no matter how high the potential at the terminals of the condenser. In these experiments a high tension induction coil, operated from a battery or from an alternate current machine, was employed to charge the condenser; but the induction coil might be replaced by an apparatus of a different kind, capable of giving electricity of such high tension. In this manner, direct or alternating currents may be converted, and in both cases the current-impulses may be of any desired frequency. When the currents charging the condenser are of the

interrupter or break, or by the use of an alternator. Earlie English investigators, to mention only Spottiswoode and J. E. H Gordon, have used a rapid break in connection with the coil Our knowledge and experience of to-day enables us to see clearly why these coils under the conditions of the test did not disclos any remarkable phenomena, and why able experimenters faile to perceive many of the curious effects which have since bee observed.

In the experiments such as performed this evening, we operat the coil either from a specially constructed alternator capable o giving many thousands of reversals of current per second, or, b disruptively discharging a condenser through the primary, we se up a vibration in the secondary circuit of a frequency of man hundred thousand or millions per second, if we so desire; and i using either of these means we enter a field as yet unexplored.

It is impossible to pursue an investigation in any novel lin ithout finally making some interesting observation or learning some useful fact. That this statement is applicable to the su ject of this lecture the many curious and unexpected phenomen which we observe afford a convincing proof. By way of illustr tion, take for instance the most obvious phenomena, those of th discharge of the induction coil.

Here is a coil which is operated by currents vibrating wi extreme rapidity, obtained by disruptively discharging a Leyde jar. It would not surprise a student were the lecturer to sa that the secondary of this coil consists of a small length of com paratively stout wire; it would not surprise him were the lecture to state that, in spite of this, the coil is capable of giving an potential which the best insulation of the turns is able to wit stand; but although he may be prepared, and even be indifferen as to the anticipated result, yet the aspect of the discharge of th coil will surprise and interest him. Every one is familiar wit the discharge of an ordinary coil; it need not be reproduce here. But, by way of contrast, here is a form of discharge of coil, the primary current of which is vibrating several hundre thousand times per second. The discharge of an ordinary co appears as a simple line or band of light. The discharge of th coil appears in the form of powerful brushes and luminou streams issuing from all points of the two straight wires attache to the terminals of the secondary. (Fig. 130.)

Now compare this phenomenon which you have just witnesse

with the discharge of a Holtz or Wimshurst machine—that other interesting appliance so dear to the experimenter. What a difference there is between these phenomena! And yet, had I made the necessary arrangements—which could have been made easily, were it not that they would interfere with other experiments—I could have produced with this coil sparks which, had I the coil

FIG. 130.

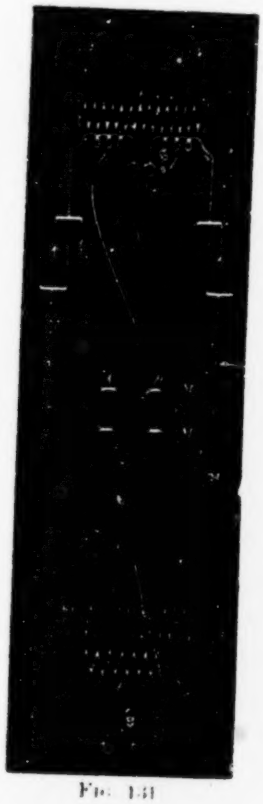


FIG. 131.

hidden from your view and only two knobs exposed, even the keenest observer among you would find it difficult, if not impossible, to distinguish from those of an influence or friction machine. This may be done in many ways—for instance, by operating the induction coil which charges the condenser from an alternating-current machine of very low frequency, and preferably adjusting the discharge circuit so that there are no oscillations set up in it. We then obtain in the secondary circuit, if the knobs are of the required size and properly set, a more or less

as, to produce each phenomenon at its best, a very careful adjustment is required. But even if imperfectly produced, as they are likely to be this evening, they are sufficiently striking to interest an intelligent audience.

Before showing some of these curious effects I must, for the sake of completeness, give a short description of the coil and other apparatus used in the experiments with the disruptive discharge this evening.

It is contained in a box B (Fig. 132) of thick boards of hard

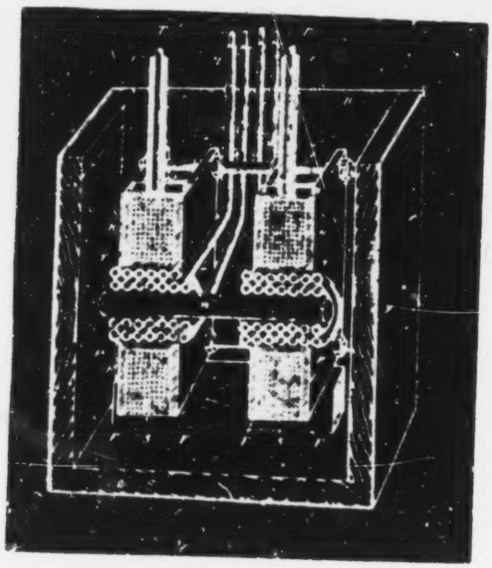


Fig. 132.

wood, covered on the outside with zinc sheet Z, which is carefully soldered all around. It might be advisable, in a strictly scientific investigation, when accuracy is of great importance, to do away with the metal cover, as it might introduce many errors, principally on account of its complex action upon the coil, as a condenser of very small capacity and as an electrostatic and electromagnetic screen. When the coil is used for such experiments as are here contemplated, the employment of the metal cover offers some practical advantages, but these are not of sufficient importance to be dwelt upon.

The coil should be placed symmetrically to the metal cover,

and the space between should, of course, not be too small, certainly not less than, say, five centimetres, but much more if possible; especially the two sides of the zinc box, which are at right angles to the axis of the coil, should be sufficiently remote from the latter, as otherwise they might impair its action and be a source of loss.

The coil consists of two spools of hard rubber R R, held apart at a distance of 10 centimetres by bolts *c* and nuts *n*, likewise of hard rubber. Each spool comprises a tube T of approximately 8 centimetres inside diameter, and 3 millimetres thick, upon which are screwed two flanges F F, 24 centimetres square, the space between the flanges being about 3 centimetres. The secondary, S S, of the best gutta percha-covered wire, has 26 layers, 10 turns in each, giving for each half a total of 260 turns. The two halves are wound oppositely and connected in series, the connection between both being made over the primary. This disposition, besides being convenient, has the advantage that when the coil is well balanced—that is, when both of its terminals T_1 T_1, are connected to bodies or devices of equal capacity—there is not much danger of breaking through to the primary, and the insulation between the primary and the secondary need not be thick. In using the coil it is advisable to attach to *both* terminals devices of nearly equal capacity, as, when the capacity of the terminals is not equal, sparks will be apt to pass to the primary. To avoid this, the middle point of the secondary may be connected to the primary, but this is not always practicable.

The primary P P is wound in two parts, and oppositely, upon a wooden spool W, and the four ends are led out of the oil through hard rubber tubes *t t*. The ends of the secondary T_1 T_1 are also led out of the oil through rubber tubes t_1 t_1 of great thickness. The primary and secondary layers are insulated by cotton cloth, the thickness of the insulation, of course, bearing some proportion to the difference of potential between the turns of the different layers. Each half of the primary has four layers, 24 turns in each, this giving a total of 96 turns. When both the parts are connected in series, this gives a ratio of conversion of about 1 : 2.7, and with the primaries in multiple, 1 : 5.4; but in operating with very rapidly alternating currents this ratio does not convey even an approximate idea of the ratio of the E. M. F.'s. in the primary and secondary circuits. The coil is held in position in the oil on wooden supports, there being about 5 centimetres

In another arrangement with the magnet I take the discharge between the rounded pole pieces themselves, which in such case are insulated and preferably provided with polished brass caps.

The employment of an intense magnetic field is of advantage principally when the induction coil or transformer which charges the condenser is operated by currents of very low frequency. In such a case the number of the fundamental discharges between the knobs may be so small as to render the currents produced in the secondary unsuitable for many experiments. The intense magnetic field then serves to blow out the arc between the knobs as soon as it is formed, and the fundamental discharges occur in quicker succession.

Instead of the magnet, a draught or blast of air may be employed with some advantage. In this case the arc is preferably

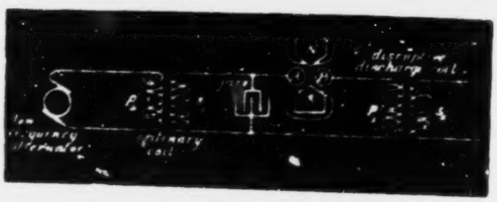


FIG. 134.

established between the knobs A B, in Fig. 134 (the knobs a b being generally joined, or entirely done away with), as in this disposition the arc is long and unsteady, and is easily affected by the draught.

When a magnet is employed to break the arc, it is better to choose the connection indicated diagrammatically in Fig. 134, as in this case the currents forming the arc are much more powerful, and the magnetic field exercises a greater influence. The use of the magnet permits, however, of the arc being replaced by a vacuum tube, but I have encountered great difficulties in working with an exhausted tube.

The other form of discharger used in these and similar experiments is indicated in Figs. 135 and 136. It consists of a number of brass pieces c c (Fig. 135), each of which comprises a spherical middle portion m with an extension e below—which is merely used to fasten the piece in a lathe when polishing up the discharging

surface, and a column above, which consists of a knurled flange surmounted by a threaded stem *l* carrying a nut *n*, by means of which a wire is fastened to the column. The flange *f* conveniently serves for holding the brass piece when fastening the

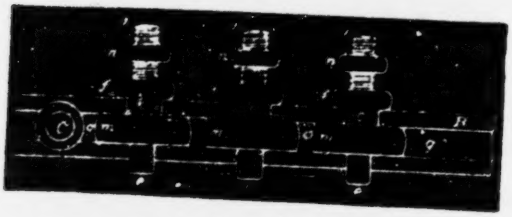


Fig. 135.

wire, and also for turning it in any position when it becomes necessary to present a fresh discharging surface. Two stout strips of hard rubber R R, with planed grooves *g g* (Fig. 136) to fit the middle portion of the pieces *c c*, serve to clamp the latter and hold them firmly in position by means of two bolts C C (of which only one is shown) passing through the ends of the strips.

In the use of this kind of discharger I have found three principal advantages over the ordinary form. First, the dielectric strength of a given total width of air space is greater when a great many small air gaps are used instead of one, which permits

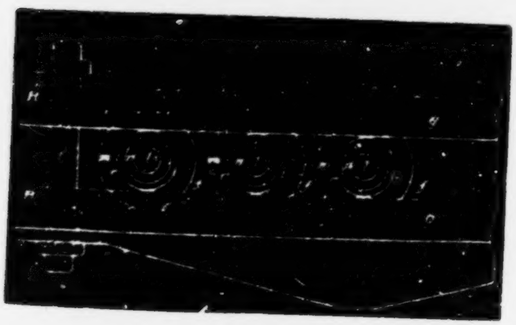


Fig. 136.

of working with a smaller length of air gap, and that means smaller loss and less deterioration of the metal; secondly, by reason of splitting the arc up into smaller arcs, the polished surfaces are made to last much longer; and, thirdly, the appa-

ratus affords some gauge in the experiments. I usually set the pieces by putting between them sheets of uniform thickness at a certain very small distance which is known from the experiments of Sir William Thomson to require a certain electromotive force to be bridged by the spark.

It should, of course, be remembered that the sparking distance is much diminished as the frequency is increased. By taking any number of spaces the experimenter has a rough idea of the electromotive force, and he finds it easier to repeat an experiment, as he has not the trouble of setting the knobs again and again. With this kind of discharger I have been able to maintain an oscillating motion without any spark being visible with the naked eye between the knobs, and they would not show a very appreciable rise in temperature. This form of discharge also lends itself to many arrangements of condensers and circuits which are often very convenient and time-saving. I have used it preferably in a disposition similar to that indicated in Fig. 111, when the currents forming the arc are small.

I may here mention that I have also used dischargers with single or multiple air gaps, in which the discharge surfaces were rotated with great speed. No particular advantage was, however, gained by this method, except in cases where the currents from the condenser were large and the keeping cool of the surfaces was necessary, and in cases when, the discharge not being oscillating of itself, the arc as soon as established was broken by the air current, thus starting the vibration at intervals in rapid succession. I have also used mechanical interrupters in many ways. To avoid the difficulties with frictional contacts, the preferred plan adopted was to establish the arc and rotate through it at great speed a rim of mica provided with many holes and fastened to a steel plate. It is understood, of course, that the employment of a magnet, air current, or other interrupter, produces no effect worth noticing, unless the self-induction, capacity and resistance are so related that there are oscillations set up upon each interruption.

I will now endeavor [illegible] of these discharge phenomena.

I have stretched across [illegible] each about [illegible] [illegible]

[illegible] on the coil is acting. Upon turning the lights off, the experimenter will see the wires distinctly illuminated by the streams issuing distinctly from their whole surface in spite of the covering, which may even be very thick. When the experiment is performed under good conditions, the light from the wires is sufficiently intense to allow distinguishing the objects in a room. To produce the best result it is, of course, necessary to adjust carefully the capacity of the jars, the arc between the knobs and the length of the wires. My experience is that calculation of the length of the wires leads, in such case, to no result whatever. The experimenter will do best to take the wires at the start very long, and then adjust by cutting off first long pieces, and then smaller and smaller ones as he approaches the right length.

A convenient way is to use an oil condenser of very small capacity, consisting of two small adjustable metal plates, in connection with this and similar experiments. In such case I take wires rather short and at the beginning set the condenser plates at maximum distance. If the streams from the wires increase by approach of the plates, the length of the wires is about right; if they diminish, the wires are too long for that frequency and potential. When a condenser is used in connection with experiments with such a coil, it should be an oil condenser by all means, as in using an air condenser considerable energy might be wasted. The wires leading to the plates in the oil should be very thin, heavily coated with some insulating compound, and provided with a conducting covering—this preferably extending under the surface of the oil. The conducting cover should not be too near the terminals, or ends, of the wire, as a spark would be apt to jump from the wire to it. The conducting coating is used to diminish the air losses, in virtue of its action as an electrostatic screen. As to the size of the vessel containing the oil, and the size of the plates, the experimenter gains at once an idea from a rough trial. The size of the plates *in oil* is, however, calculable, as the dielectric losses are very small.

In the preceding experiment it is of considerable interest to know what relation the quantity of the light emitted bears to the frequency and potential of the electric impulses. My opinion is that the heat as well as light effects produced should be proportionate, under otherwise equal conditions of test, to the product of frequency and square of potential, but the experimental verification of the law, whatever it may be, would be exceedingly

some experiments, and many times convenient for the purposes of adjustment. I cover the secondary with wax, and turn it off in a lathe to a diameter slightly smaller than the inside of the primary coil. The latter I provide with a handle reaching out of the oil, which serves to shift it in any position along the secondary.

I will now venture to make, in regard to the general manipulation of induction coils, a few observations bearing upon points which have not been fully appreciated in earlier experiments with such coils, and are even now often overlooked.

The secondary of the coil possesses usually such a high self-induction that the current through the wire is inappreciable, and may be so even when the terminals are joined by a conductor of small resistance. If capacity is added to the terminals, the self-induction is counteracted, and a stronger current is made to flow through the secondary, though its terminals are insulated from each other. To one entirely unacquainted with the properties of alternating currents nothing will look more puzzling. This feature was illustrated in the experiment performed at the beginning with the top plates of wire gauze attached to the terminals and the rubber plate. When the plates of wire gauze were close together, and a small arc passed between them, the arc *prevented* a strong current from passing through the secondary, because it did away with the capacity on the terminals; when the rubber plate was inserted between, the capacity of the condenser formed counteracted the self-induction of the secondary, a stronger current passed now, the coil performed more work, and the discharge was by far more powerful.

The first thing, then, in operating the induction coil is to combine capacity with the secondary to overcome the self-induction. If the frequencies and potentials are very high, gaseous matter should be carefully kept away from the charged surfaces. If Leyden jars are used, they should be immersed in oil, as otherwise considerable dissipation may occur if the jars are greatly strained. When high frequencies are used, it is of equal importance to combine a condenser with the primary. One may use a condenser connected to the ends of the primary or to the terminals of the alternator, but the latter is not to be recommended, as the machine might be injured. The best way is undoubtedly to use the condenser in series with the primary and with the alternator, and to adjust its capacity so as to annul the

self-induction of both the latter. The condenser should be adjustable by very small steps, and for a finer adjustment a small oil condenser with movable plates may be used conveniently.

I think it best at this juncture to bring before you a phenomenon, observed by me some time ago, which to the purely scientific investigator may perhaps appear more interesting than any of the results which I have the privilege to present to you this evening.

It may be quite properly ranked among the brush phenomena—in fact, it is a brush, formed at, or near, a single terminal in high vacuum.

In bulbs provided with a conducting terminal, though it be of

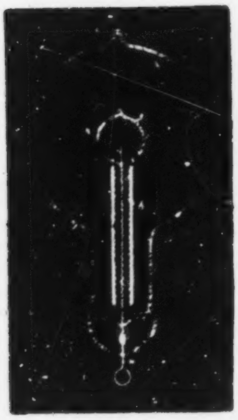


FIG. 141

FIG. 142

aluminum, the brush has but an ephemeral existence, and cannot, unfortunately, be indefinitely preserved in its most sensitive state, even in a bulb devoid of any conducting electrode. In studying the phenomenon, by all means a bulb having no leading-in wire should be used. I have found it best to use bulbs constructed as indicated in Figs. 141 and 142.

In Fig. 141 the bulb comprises an incandescent lamp globe L, in the neck of which is sealed a barometer tube b, the end of which is blown out to form a small sphere s. This sphere should be sealed as closely as possible in the centre of the large globe. Before sealing, a thin tube t, of aluminum sheet, may be slipped in the barometer tube, but it is not important to employ it.

I have been unable to produce the phenomenon with the disruptive discharge coil, although every other of these phenomena can be well produced by it—many, in fact, much better than with coils operated from an alternator.

It may be possible to produce the brush by impulses of one direction, or even by a steady potential, in which case it would be still more sensitive to magnetic influence.

In operating an induction coil with rapidly alternating currents, we realize with astonishment, for the first time, the great importance of the relation of capacity, self-induction and frequency as regards the general results. The effects of capacity are the most striking, for in these experiments, since the self-induction and frequency both are high, the critical capacity is very small, and need be but slightly varied to produce a very considerable change. The experimenter may bring his body in contact with the terminals of the secondary of the coil, or attach to one or both terminals insulated bodies of very small bulk, such as bulbs, and he may produce a considerable rise or fall of potential, and greatly affect the flow of the current through the primary. In the experiment before shown, in which a brush appears at a wire attached to one terminal, and the wire is vibrated when the experimenter brings his insulated body in contact with the other terminal of the coil, the sudden rise of potential was made evident.

I may show you the behavior of the coil in another manner which possesses a feature of some interest. I have here a little light fan of aluminum sheet, fastened to a needle and arranged to rotate freely in a metal piece screwed to one of the terminals of the coil. When the coil is set to work, the molecules of the air are rhythmically attracted and repelled. As the force with which they are repelled is greater than that with which they are attracted, it results that there is a repulsion exerted on the surfaces of the fan. If the fan were made simply of a metal sheet, the repulsion would be equal on the opposite sides, and would produce no effect. But if one of the opposing surfaces is screened, or if, generally speaking, the bombardment on this side is weakened in some way or other, there remains the repulsion exerted upon the other, and the fan is set in rotation. The screening is best effected by fastening upon one of the opposing sides of the fan insulated conducting coatings, or, if the fan is made in the shape of an ordinary propeller screw, by fastening on one

show you is that this motor rotates with *one single* connection between it and the generator; that is to say, one terminal of the motor is connected to one terminal of the generator—in this case the secondary of a high-tension induction coil—the other terminals of motor and generator being insulated in space. To produce rotation it is generally (but not absolutely) necessary to connect the free end of the motor coil to an insulated body of some size. The experimenter's body is more than sufficient. If he touches the free terminal with an object held in the hand, a current passes through the coil and the copper disc is set in rotation. If an exhausted tube is put in series with the coil, the tube lights brilliantly, showing the passage of a strong current. In-

FIG. 146.

stead of the experimenter's body, a small metal sheet suspended on a cord may be used with the same result. In this case the plate acts as a condenser in series with the coil. It counteracts the self-induction of the latter and allows a strong current to pass. In such a combination, the greater the self-induction of the coil the smaller need be the plate, and this means that a lower frequency, or eventually a lower potential, is required to operate the motor. A single coil wound upon a core has a high self-induction; for this reason, principally, this type of motor was chosen to perform the experiment. Were a secondary closed coil wound upon the core, it would tend to diminish the self-

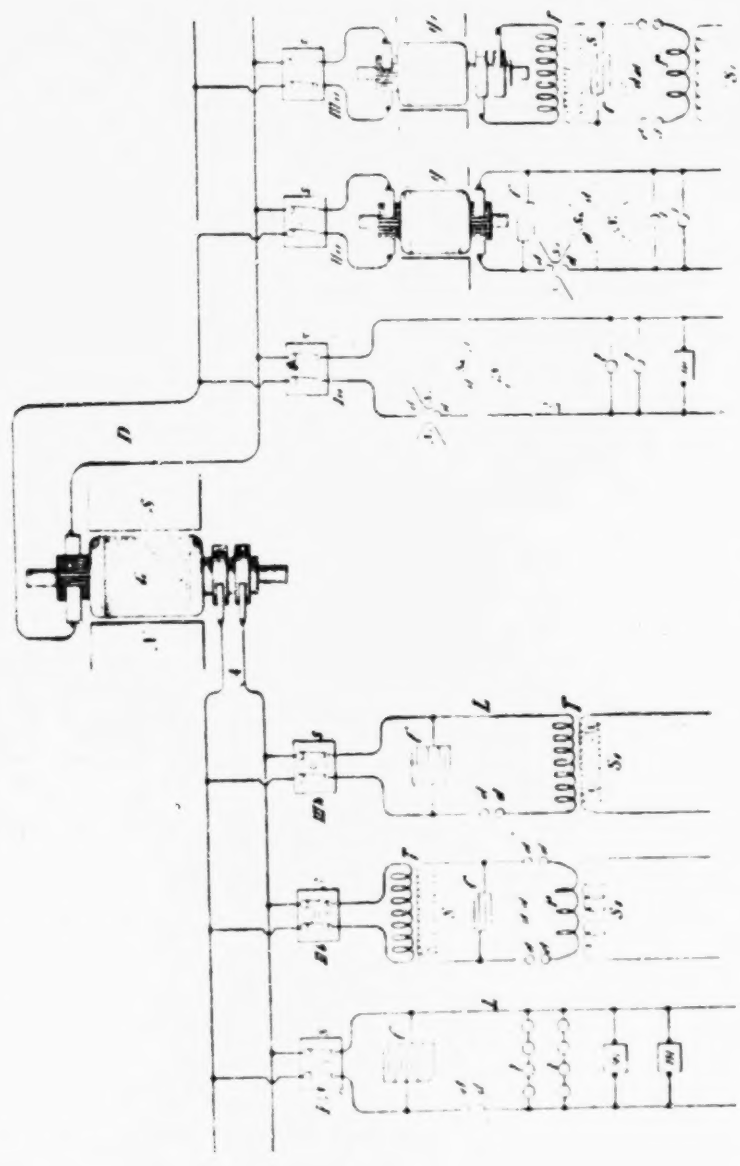


Fig. 165.

plan is to charge condensers, from a direct or alternate current source, preferably of high-tension, and to discharge them disruptively while observing well-known conditions necessary to maintain the oscillations of the current. In view of the general interest taken in high-frequency currents and effects producible by them, it seems to me advisable to dwell at some length upon this method of conversion. In order to give you a clear idea of the action, I will suppose that a continuous-current generator is employed, which is often very convenient. It is desirable that the generator should possess such high tension as to be able to break through a small air space. If this is not the case, then auxiliary means have to be resorted to, some of which will be indicated subsequently. When the condensers are charged to a certain potential, the air, or insulating space, gives way and a disruptive discharge occurs. There is then a sudden rush of current and generally a large portion of accumulated electrical energy spends itself. The condensers are thereupon quickly charged and the same process is repeated in more or less rapid succession. To produce such sudden rushes of current it is necessary to observe certain conditions. If the rate at which the condensers are discharged is the same as that at which they are charged, then, clearly, in the assumed case the condensers do not come into play. If the rate of discharge be smaller than the rate of charging, then, again, the condensers cannot play an important part. But if, on the contrary, the rate of discharging is greater than that of charging, then a succession of rushes of current is obtained. It is evident that, if the rate at which the energy is dissipated by the discharge is very much greater than the rate of supply to the condensers, the sudden rushes will be comparatively few, with long-time intervals between. This always occurs when a condenser of considerable capacity is charged by means of a comparatively small machine. If the rates of supply and dissipation are not widely different, then the rushes of current will be in quicker succession, and this the more, the more nearly equal both the rates are, until limitations incident to each case and depending upon a number of causes are reached. Thus we are able to obtain from a continuous-current generator as rapid a succession of discharges as we like. Of course, the higher the tension of the generator, the smaller need be the capacity of the condensers, and for this reason, principally, it is of advantage to employ a generator of very high tension. Besides, such a generator permits the attaining of greater rates of vibration.

The rushes of current may be of the same direction under the conditions before assumed, but most generally there is an oscillation superimposed upon the fundamental vibration of the current. When the conditions are so determined that there are no oscillations, the current impulses are unidirectional and thus a means is provided of transforming a continuous current of high tension, into a direct current of lower tension, which I think may find employment in the arts.

This method of conversion is exceedingly interesting and I was much impressed by its beauty when I first conceived it. It is ideal in certain respects. It involves the employment of no mechanical devices of any kind, and it allows of obtaining currents of any desired frequency from an ordinary circuit, direct or alternating. The frequency of the fundamental discharges depending on the relative rates of supply and dissipation can be readily varied within wide limits, by simple adjustments of these quantities, and the frequency of the superimposed vibration by the determination of the capacity, self-induction and resistance of the circuit. The potential of the currents, again, may be raised as high as any insulation is capable of withstanding safely by combining capacity and self-induction or by induction in a secondary, which need have but comparatively few turns.

As the conditions are often such that the intermittence or oscillation does not readily establish itself, especially when a direct current source is employed, it is of advantage to associate an interrupter with the arc, as I have, some time ago, indicated the use of an air-blast or magnet, or other such device readily at hand. The magnet is employed with special advantage in the conversion of direct currents, as it is then very effective. If the primary source is an alternate current generator, it is desirable, as I have stated on another occasion, that the frequency should be low, and that the current forming the arc be large, in order to render the magnet more effective.

A form of such discharger with a magnet which has been found convenient, and adopted after some trials, in the conversion of direct currents particularly, is illustrated in Fig. 166. N S are the pole pieces of a very strong magnet which is excited by a coil C. The pole pieces are slotted for adjustment and can be fastened in any position by screws $s\ s_1$. The discharge rods $d\ d_1$, thinned down on the ends in order to allow a closer approach of the magnetic pole pieces, pass through the columns of brass $b\ b_1$ and are fastened in position by screws $s_2\ s_2$. Springs $r\ r_1$ and collars $c\ c_1$

are slipped on the rods, the latter serving to set the points of the rods at a certain suitable distance by means of screws $s_1 s_2$, and the former to draw the points apart. When it is desired to start the arc, one of the large rubber handles $h\ h_1$ is tapped quickly with the hand, whereby the points of the rods are brought in contact but are instantly separated by the springs $r\ r_1$. Such an arrangement has been found to be often necessary, namely in cases when the E. M. F. was not large enough to cause the discharge to break through the gap, and also when it was desirable to avoid short circuiting of the generator by the metallic contact of the rods. The rapidity of the interruptions of the current with a magnet depends on the intensity of the magnetic field and on the

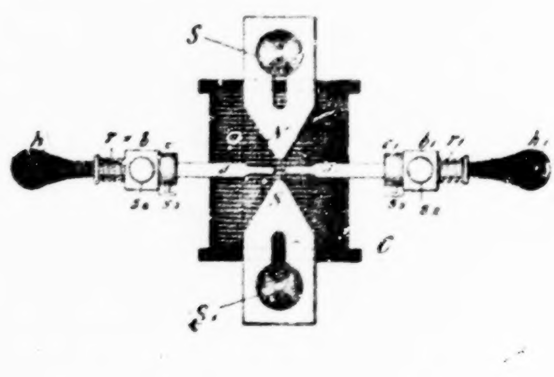
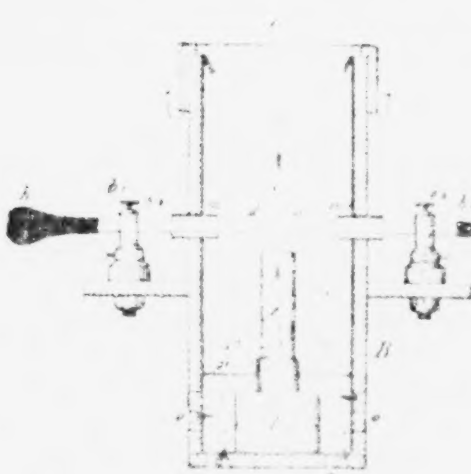


FIG. 166.

potential difference at the end of the arc. The interruptions are generally in such quick succession as to produce a musical sound. Years ago it was observed that when a powerful induction coil is discharged between the poles of a strong magnet, the discharge produces a loud noise not unlike a small pistol shot. It was vaguely stated that the spark was intensified by the presence of the magnetic field. It is now clear that the discharge current, flowing for some time, was interrupted a great number of times by the magnet, thus producing the sound. The phenomenon is especially marked when the field circuit of a large magnet or dynamo is broken in a powerful magnetic field.

A[illegible] current through the gap is comparatively [illegible] advantage to slip on the points of the discharge rods pieces of hard carbon and let the arc play between the carbon pieces. This preserves the rods, and besides has the advantage of keeping the air space hotter, as the heat is not conducted away as quickly through the carbons, and the result is that a smaller [illegible] in the arc gap is required to maintain a succession of discharges.

Another form of discharger which may be employed with advantage in some cases, is illustrated in Fig. [illegible]. In this form the discharge rods $d\ d$ pass through perforations [illegible]



It is desirable to exclude the light as perfectly as possible, as it interferes with some experiments. This form of discharger is simple and very effective when properly manipulated. The air being warmed to a certain temperature, has its insulating power impaired; it becomes dielectrically weak, as it were, and the consequence is that the arc can be established at much greater distance. The arc should, of course, be sufficiently insulating to allow the discharge to pass through the gap *disruptively*. The arc formed under such conditions, when long, may be made extremely sensitive, and the weak draught through the lamp chimney *c* is quite sufficient to produce rapid interruptions. The adjustment is made by regulating the temperature and velocity of the draught. Instead of using the lamp, it answers the purpose to provide for a draught of warm air in other ways. A very simple way which has been practiced is to enclose the arc in a long vertical tube, with plates on the top and bottom for regulating the temperature and velocity of the air current. Some provision had to be made for deadening the sound.

The air may be rendered dielectrically weak also by rarefaction. Dischargers of this kind have likewise been used by me in connection with a magnet. A large tube is for this purpose provided with heavy electrodes of carbon or metal, between which the discharge is made to pass, the tube being placed in a powerful magnetic field. The exhaustion of the tube is carried to a point at which the discharge breaks through easily, but the pressure should be more than 75 millimetres, at which the ordinary thread discharge occurs. In another form of discharger, combining the features before mentioned, the discharge was made to pass between two adjustable magnetic pole pieces, the space between them being kept at an elevated temperature.

It should be remarked here that when such, or interrupting devices of any kind, are used and the currents are passed through the primary of a disruptive discharge coil, it is not, as a rule, of advantage to produce a number of interruptions of the current per second greater than the natural frequency of vibration of the dynamo supply circuit, which is ordinarily small. It should also be pointed out here, that while the devices mentioned in connection with the disruptive discharge are advantageous under certain conditions, they may be sometimes a source of trouble, as they produce intermittences and other irregularities in the vibration which it would be very desirable to overcome.

There is, I regret to say, in this beautiful method of conversion a defect, which fortunately is not vital, and which I have been gradually overcoming. I will best call attention to this defect and indicate a fruitful line of work, by comparing the electrical process with its mechanical analogue. The process may be illustrated in this manner. Imagine a tank with a wide opening at the bottom, which is kept closed by spring pressure, but so that it snaps off *suddenly* when the liquid in the tank has reached a certain height. Let the fluid be supplied to the tank by means of a pipe feeding at a certain rate. When the critical height of the liquid is reached, the spring gives way and the bottom of the tank drops out. Instantly the liquid falls through the wide opening, and the spring, reasserting itself, closes the bottom again. The tank is now filled, and after a certain time interval the same process is repeated. It is clear, that if the pipe feeds the fluid quicker than the bottom outlet is capable of letting it pass through, the bottom will remain off and the tank will still overflow. If the rates of supply are exactly equal, then the bottom lid will remain partially open and no vibration of the same and of the liquid column will generally occur, though it might, if started by some means. But if the inlet pipe does not feed the fluid fast enough for the outlet, then there will be always vibration. Again, in such case, each time the bottom flaps up or down, the spring and the liquid column, if the pliability of the spring and the inertia of the moving parts are properly chosen, will perform independent vibrations. In this analogue the fluid may be likened to electricity or electrical energy, the tank to the condenser, the spring to the dielectric, and the pipe to the conductor through which electricity is supplied to the condenser. To make this analogy quite complete it is necessary to make the assumption, that the bottom, each time it gives way, is knocked violently against a non-elastic stop, this impact involving some loss of energy; and that, besides, some dissipation of energy results due to frictional losses. In the preceding analogue the liquid is supposed to be under a steady pressure. If the presence of the fluid be assumed to vary rhythmically, this may be taken as corresponding to the case of an alternating current. The process is then not quite as simple to consider, but the action is the same in principle.

It is desirable, in order to maintain the vibration economically, to reduce the impact and frictional losses

As regards the latter, which in the electrical analogue correspond to the losses due to the resistance of the circuits, it is impossible to obviate them entirely, but they can be reduced to a minimum by a proper selection of the dimensions of the circuits and by the employment of thin conductors in the form of strands. But the loss of energy caused by the first breaking through of the dielectric—which in the above example corresponds to the violent knock of the bottom against the inelastic stop—would be more important to overcome. At the moment of the breaking through the air space has a very high resistance, which is probably reduced to a very small value when the current has reached some strength, and the space is brought to a high temperature. It would materially diminish the loss of energy if the space were always kept at an extremely high temperature, but then there would be no disruptive break. By warming the space moderately by means of a lamp or otherwise, the economy as far as the arc is concerned is sensibly increased. But the magnet or other interrupting device does not diminish the loss in the arc. Likewise, a jet of air only facilitates the carrying off of the energy. Air, or a gas in general, behaves curiously in this respect. When two bodies charged to a very high potential, discharge disruptively through an air space, any amount of energy may be carried off by the air. This energy is evidently dissipated by bodily carriers, in impact and collisional losses of the molecules. The exchange of the molecules in the space occurs with inconceivable rapidity. A powerful discharge taking place between two electrodes, they may remain entirely cool, and yet the loss in the air may represent any amount of energy. It is perfectly practicable, with very great potential differences in the gap, to dissipate several horse power in the arc of the discharge without even noticing a small increase in the temperature of the electrodes. All the frictional losses occur then practically in the air. If the exchange of the air molecules is prevented, as by enclosing the air hermetically, the gas inside of the vessel is brought quickly to a high temperature, even with a very small discharge. It is difficult to estimate how much of the energy is lost in sound waves, audible or not, in a powerful discharge. When the currents through the gap are large, the electrodes may become rapidly heated, but this is not a reliable measure of the energy wasted in the arc, as the loss through the gap itself may be comparatively small. The air or a gas in general is, at ordinary pressure at least,

clearly not the best medium through which a disruptive discharge should occur. Air or other gas under great pressure is of course a much more suitable medium for the discharge gap. I have carried on long-continued experiments in this direction, unfortunately less practicable on account of the difficulties and expense in getting air under great pressure. But even if the medium in the discharge space is solid or liquid, still the same losses take place, though they are generally smaller, for just as soon as the arc is established, the solid or liquid is volatilized. Indeed, there is no body known which would not be disintegrated by the arc, and it is an open question among scientific men, whether an arc discharge could occur at all in the air itself without the particles of the electrodes being torn off. When the current through the gap is very small and the arc very long, I believe that a relatively considerable amount of heat is taken up in the disintegration of the electrodes, which partially on this account may remain quite cold.

The ideal medium for a discharge gap should only *crack*, and the ideal electrode should be of some material which cannot be disintegrated. With small currents through the gap it is best to employ aluminum, but not when the currents are large. The disruptive break in the air, or more or less in any ordinary medium, is not of the nature of a crack, but it is rather comparable to the piercing of innumerable bullets through a mass offering great frictional resistances to the motion of the bullets, this involving considerable loss of energy. A medium which would merely crack when strained electrostatically—and this possibly might be the case with a perfect vacuum, that is, pure ether—would involve a very small loss in the gap, so small as to be entirely negligible, at least theoretically, because a crack may be produced by an infinitely small displacement. In exhausting an oblong bulb provided with two aluminum terminals, with the greatest care, I have succeeded in producing such a vacuum that the secondary discharge of a disruptive discharge coil would break disruptively through the bulb in the form of fine spark streams. The curious point was that the discharge would completely ignore the terminals and start far behind the two aluminum plates which served as electrodes. This extraordinary high vacuum could only be maintained for a very short while. To return to the ideal medium, think, for the sake of illustration, of a piece of glass or similar body clamped in a vice, and the latter tightened more and

more. At a certain point a minute increase of the pressure will cause the glass to crack. The loss of energy involved in splitting the glass may be practically nothing, for though the force is great, the displacement need be but extremely small. Now imagine that the glass would possess the property of closing again perfectly the crack upon a minute diminution of the pressure. This is the way the dielectric in the discharge space should behave. But inasmuch as there would be always some loss in the gap, the medium, which should be continuous, should exchange through the gap at a rapid rate. In the preceding example, the glass being perfectly closed, it would mean that the dielectric in the discharge space possesses a great insulating power; the glass being cracked, it would signify that the medium in the space is a good conductor. The dielectric should vary enormously in resistance by minute variations of the E. M. F. across the discharge space. This condition is attained, but in an extremely imperfect manner, by warming the air space to a certain critical temperature, dependent on the E. M. F. across the gap, or by otherwise impairing the insulating power of the air. But as a matter of fact the air does never break down *disruptively*, if this term be rigorously interpreted, for before the sudden rush of the current occurs, there is always a weak current preceding it, which rises first gradually and then with comparative suddenness. That is the reason why the rate of change is very much greater when glass, for instance, is broken through, than when the break takes place through an air space of equivalent dielectric strength. As a medium for the discharge space, a solid, or even a liquid, would be preferable therefor. It is somewhat difficult to conceive of a solid body which would possess the property of closing instantly after it has been cracked. But a liquid, especially under great pressure, behaves practically like a solid, while it possesses the property of closing the crack. Hence it was thought that a liquid insulator might be more suitable as a dielectric than air. Following out this idea, a number of different forms of dischargers in which a variety of such insulators, sometimes under great pressure, were employed, have been experimented upon. It is thought sufficient to dwell in a few words upon one of the forms experimented upon. One of these dischargers is illustrated in Figs. 168*a* and 168*b*.

A hollow metal pulley P (Fig. 168*a*), was fastened upon an arbor *a*, which by suitable means was rotated at a considerable

speed. On the inside of the pulley, but disconnected from the same, was supported a thin disc *h* (which is shown thick for the sake of clearness), of hard rubber in which there were embedded two metal segments *s s* with metallic extensions *e e* into which were screwed conducting terminals *t t* covered with thick tubes of hard rubber *t t*. The rubber disc *h* with its metallic segments *s s*, was finished in a lathe, and its entire surface highly polished so as to offer the smallest possible frictional resistance to the motion through a fluid. In the hollow of the pulley an insulating liquid such as a thin oil was poured so as to reach very nearly to the opening left in the flange *f*, which was screwed tightly on the front side of the pulley. The terminals *t t*, were connected to the opposite coatings of a battery of condensers so that the discharge occurred through the liquid. When the pulley was rotated, the liquid was forced against the rim of the pulley and considerable fluid pressure resulted. In this simple way the discharge gap

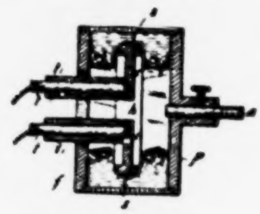


FIG. 168a.

FIG. 168b

was filled with a medium which behaved practically like a solid, which possessed the quality of closing instantly upon the occurrence of the break, and which moreover was circulating through the gap at a rapid rate. Very powerful effects were produced by discharges of this kind with liquid interrupters, of which a number of different forms were made. It was found that, as expected, a longer spark for a given length of wire was obtainable in this way than by using air as an interrupting device. Generally the speed, and therefore also the fluid pressure, was limited by reason of the fluid friction, in the form of discharger described, but the practically obtainable speed was more than sufficient to produce a number of breaks suitable for the circuits ordinarily used. In such instances the metal pulley P was provided with a few projections inwardly, and a definite number of breaks was then produced which could be computed from the speed of

duced without the discharge gap, and there might even not be any quicker superimposed vibration; yet the differences of potential at the various points of the circuit, the impedance and other phenomena, dependent upon the rate of change, will bear no similarity in the two cases. Thus, when working with currents discharging disruptively, the element chiefly to be considered is not the frequency, as a student might be apt to believe, but the rate of change per unit of time. With low frequencies in a certain measure the same effects may be obtained as with high frequencies, provided the rate of change is sufficiently great. So if a low frequency current is raised to a potential of, say, 75,000 volts, and the high tension current passed through a series of high resistance lamp filaments, the importance of the rarefied gas surrounding the filament is clearly noted, as will be seen later; or, if a low frequency current of several thousand amperes is passed through a metal bar, striking phenomena of impedance are observed, just as with currents of high frequencies. But it is, of course, evident that with low frequency currents it is impossible to obtain such rates of change per unit of time as with high frequencies, hence the effects produced by the latter are much more prominent. It is deemed advisable to make the preceding remarks, inasmuch as many more recently described effects have been unwittingly identified with high frequencies. Frequency alone in reality does not mean anything, except when an undisturbed harmonic oscillation is considered.

In the branch [illegible] a similar disposition to that in I*b* is illustrated, with the difference that the currents discharging through the gap *d d* are used to induce currents in the secondary S of a transformer T. In such case the secondary should be provided with an adjustable condenser for the purpose of tuning it to the primary.

II*b* illustrates a plan of alternate current high frequency conversion which is most frequently used and which is found to be most convenient. This plan has been dwelt upon in detail on previous occasions and need not be described here.

Some of these results were obtained by the use of a high frequency alternator. A description of such machines will be found in my original paper before the American Institute of Electrical Engineers, and in periodicals of that period, notably in THE ELECTRICAL ENGINEER of March 18, 1891.

I will now proceed with the experiments.

coils; also by varying the frequency and potential of the currents. But it is perhaps of greater interest to note, that the lamp increases in brightness when the plate is disconnected (Fig. 179a). In this case all the energy the primary receives is now sunk into it, like the charge of a battery in an ocean cable, but most of that energy is recovered through the secondary and used to light the lamp. The current traversing the primary is strongest at the end b which is connected to the terminal T_1 of the induction coil, and

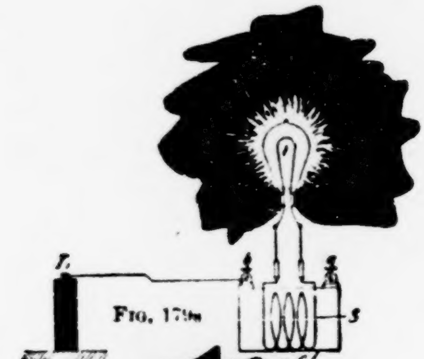


Fig. 179a.

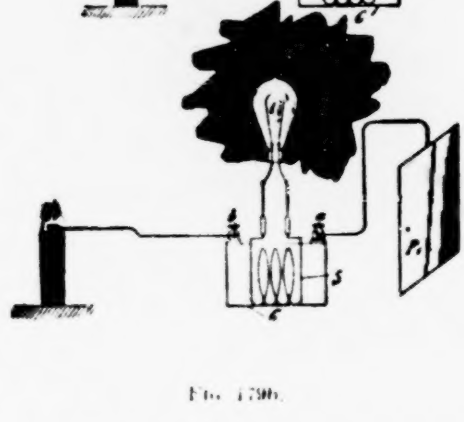


Fig. 179b.

diminishes in strength towards the remote end a. But the dynamic inductive effect exerted upon the secondary s is now greater than before, when the suspended plate was connected to the primary. These results might have been produced by a number of causes. For instance, the plate P_1 being connected, the reaction from the coil c may be such as to diminish the potential at the terminal T_1 of the induction coil, and therefore weaken the current through the primary of the coil c. Or the disconnecting

of the plate may diminish the capacity effect with relation to the primary of the latter coil to such an extent that the current through it is diminished, though the potential at the terminal T_1 of the induction coil may be the same or even higher. Or the result might have been produced by the change of phase of the primary and secondary currents and consequent reaction. But the chief determining factor is the relation of the self-induction and capacity of coil C and plate P_1 and the frequency of the currents. The greater brightness of the filament in Fig. 179*a*, is, however, in part due to the heating of the rarefied gas in the lamp by electrostatic induction, which, as before remarked, is greater when the suspended plate is disconnected.

Still another feature of some interest I may here bring to your attention. When the insulated plate is disconnected and the secondary of the coil opened, by approaching a small object to the secondary, but very small sparks can be drawn from it, showing that the electrostatic induction is small in this case. But upon the secondary being closed upon itself or through the lamp, the filament glowing brightly, strong sparks are obtained from the secondary. The electrostatic induction is now much greater, because the closed secondary determines a greater flow of current through the primary and principally through that half of it which is connected to the induction coil. If now the bulb be grasped with the hand, the capacity of the secondary with reference to the primary is augmented by the experimenter's body and the luminosity of the filament is increased, the incandescence now being due partly to the flow of current through the filament and partly to the molecular bombardment of the rarefied gas in the bulb.

The preceding experiments will have prepared one for the next following results of interest, obtained in the course of these investigations. Since I can pass a current through an insulated wire merely by connecting one of its ends to the source of electrical energy, since I can induce by it another current, magnetize an iron core, and, in short, perform all operations as though a return circuit were used, clearly I can also drive a motor by the aid of only one wire. On a former occasion I have described a simple form of motor comprising a single exciting coil, an iron core and disc. Fig. 180 illustrates a modified way of operating such an alternate current motor by currents induced in a transformer connected to one lead, and several other arrangements of circuits

plate P_3. On the primaries are wound secondaries s and s_1, of coarse wire, connected to the devices d and l respectively. By varying the distances of the condenser plates c and c_1, and c and c_1 the currents through the secondaries s and s_1 are varied in intensity. The curious feature is the great sensitiveness, the slightest change in the distance of the plates producing considerable variations in the intensity or strength of the currents. The sensitiveness may be rendered extreme by making the frequency such, that the primary itself, without any plate attached to its free end, satisfies, in conjunction with the closed secondary, the condition of resonance. In such condition an extremely small change in the capacity of the free terminal produces great variations. For instance, I have been able to adjust the conditions so that the mere approach of a person to the coil produces a considerable change in the brightness of the lamps attached to the secondary. Such observations and experiments possess, of course, at present, chiefly scientific interest, but they may soon become of practical importance.

Very high frequencies are of course not practicable with motors on account of the necessity of employing iron cores. But one may use sudden discharges of low frequency and thus obtain certain advantages of high-frequency currents without rendering the iron core entirely incapable of following the changes and without entailing a very great expenditure of energy in the core. I have found it quite practicable to operate with such low frequency disruptive discharges of condensers, alternating-current motors. A certain class of such motors which I advanced a few years ago, which contain closed secondary circuits, will rotate quite vigorously when the discharges are directed through the exciting coils. One reason that such a motor operates so well with these discharges is that the difference of phase between the primary and secondary currents is 90 degrees, which is generally not the case with harmonically rising and falling currents of low frequency. It might not be without interest to show an experiment with a simple motor of this kind, inasmuch as it is commonly thought that disruptive discharges are unsuitable for such purposes. The motor is illustrated in Fig. 182. It comprises a rather large iron core i with slots on the top into which are embedded thick copper washers c c. In proximity to the core is a freely-movable metal disc D. The core is provided with a primary exciting coil c_1 the ends a and b of which are connected to

100-volt and the latter a 50-volt are placed in certain positions as indicated, the 100-volt lamp being below the 50-volt lamp. When the arc is playing at $d\ d$ and the sudden discharges are passed through the bars $B\ B_1$, the 50-volt lamp will, as a rule, burn brightly, or at least this result is easily secured, while the 100-volt lamp will burn very low or remain quite dark, Fig. 183*b*. Now the bars $B\ B_1$ may be joined at the top by a thick cross bar B_2 and it is quite easy to maintain the 100-volt lamp at full candle-power while the 50-volt lamp remains dark, Fig. 183*c*. These results, as I have pointed out previously, should not be considered to be due exactly to frequency but rather to the time rate of change which may be great, even with low frequencies. A great many other results of the same kind, equally interesting, especially to those who are only used to manipulate steady currents, may be obtained and they afford precious clues in investigating the nature of electric currents.

In the preceding experiments I have already had occasion to show some light phenomena and it would now be proper to study these in particular; but to make this investigation more complete I think it necessary to make first a few remarks on the subject of electrical resonance which has to be always observed in carrying out these experiments.

ON ELECTRICAL RESONANCE.

The effects of resonance are being more and more noted by engineers and are becoming of great importance in the practical operation of apparatus of all kinds with alternating currents. A few general remarks may therefore be made concerning these effects. It is clear, that if we succeed in employing the effects of resonance practically in the operation of electric devices the return wire will, as a matter of course, become unnecessary, for the electric vibration may be conveyed with one wire just as well as, and sometimes even better than, with two. The question first to answer is, then, whether pure resonance effects are producible. Theory and experiment both show that such is impossible in Nature, for as the oscillation becomes more and more vigorous, the losses in the vibrating bodies and environing media rapidly increase and necessarily check the vibration which otherwise would go on increasing forever. It is a fortunate circumstance that pure resonance is not producible, for if it were there is no telling what dangers might not lie in wait for the innocent experimenter. But to a

any degree resonance is producible, the magnitude of the effects being limited by the imperfect conductivity and imperfect elasticity of the media or, generally stated, by frictional losses. The smaller these losses, the more striking are the effects. The same is the case in mechanical vibration. A stout steel bar may be set in vibration by drops of water falling upon it at proper intervals; and with glass, which is more perfectly elastic, the resonance effect is still more remarkable, for a goblet may be burst by singing into it a note of the proper pitch. The electrical resonance is the more perfectly attained, the smaller the resistance or the impedance of the conducting path and the more perfect the dielectric. In a Leyden jar discharging through a short stranded cable of thin wires these requirements are probably best fulfilled, and the resonance effects are therefore very prominent. Such is not the case with dynamo machines, transformers and their circuits, or with commercial apparatus in general in which the presence of iron cores complicates the action or renders it impossible. In regard to Leyden jars with which resonance effects are frequently demonstrated, I would say that the effects observed are often *attributed* but are seldom *due* to true resonance, for an error is quite easily made in this respect. This may be undoubtedly demonstrated by the following experiment. Take, for instance, two large insulated metallic plates or spheres which I shall designate A and B; place them at a certain small distance apart and charge them from a frictional or influence machine to a potential so high that just a slight increase of the difference of potential between them will cause the small air or insulating space to break down. This is easily reached by making a few preliminary trials. If now another plate—fastened on an insulating handle and connected by a wire to one of the terminals of a high tension secondary of an induction coil, which is maintained in action by an alternator (preferably high frequency)—is approached to one of the charged bodies A or B, so as to be nearer to either one of them, the discharge will invariably occur between them; at least it will, if the potential of the coil in connection with the plate is sufficiently high. But the explanation of this will soon be found in the fact that the approached plate acts inductively upon the bodies A and B and causes a spark to pass between them. When this spark occurs, the charges which were previously imparted to these bodies from the influence machine, must needs be lost, since the bodies are brought in electri-

cal connection through the arc formed. Now this arc is formed whether there be resonance or not. But even if the spark would not be produced, still there is an alternating E. M. F. set up between the bodies when the plate is brought near one of them; therefore the approach of the plate, if it *does* not always actually, will, at any rate, *tend* to break down the air space by inductive action. Instead of the spheres or plates A and B we may take the coatings of a Leyden jar with the same result, and in place of the machine,—which is a high frequency alternator preferably, because it is more suitable for the experiment and also for the argument,—we may take another Leyden jar or battery of jars. When such jars are discharging through a circuit of low resistance the same is traversed by currents of very high frequency. The plate may now be connected to one of the coatings of the second jar, and when it is brought near to the first jar just previously charged to a high potential from an influence machine, the result is the same as before, and the first jar will discharge through a small air space upon the second being caused to discharge. But both jars and their circuits need not be tuned any closer than a basso profundo is to the note produced by a mosquito, as small sparks will be produced through the air space, or at least the latter will be considerably more strained owing to the setting up of an alternating E. M. F. by induction, which takes place when one of the jars begins to discharge. Again another error of a similar nature is quite easily made. If the circuits of the two jars are run parallel and close together, and the experiment has been performed of discharging one by the other, and now a coil of wire be added to one of the circuits whereupon the experiment does not succeed, the conclusion that this is due to the fact that the circuits are now not tuned, would be far from being safe. For the two circuits act as condenser coatings and the addition of the coil to one of them is equivalent to bridging them, at the point where the coil is placed, by a small condenser, and the effect of the latter might be to prevent the spark from jumping through the discharge space by diminishing the alternating E. M. F. acting across the same. All these remarks, and many more which might be added but for fear of wandering too far from the subject, are made with the pardonable intention of cautioning the unsuspecting student, who might gain an entirely unwarranted opinion of his skill at seeing every experiment succeed; but they are in no way [illegible] the experienced as novel observations.

In order to make reliable observations of electric resonance effects it is very desirable, if not necessary, to employ an alternator giving currents which rise and fall harmonically, as in working with make and break currents the observations are not always trustworthy, since many phenomena, which depend on the rate of change, may be produced with widely different frequencies. Even when making such observations with an alternator one is apt to be mistaken. When a circuit is connected to an alternator there are an indefinite number of values for capacity and self-induction which, in conjunction, will satisfy the condition of resonance. So there are in mechanics an infinite number of tuning forks which will respond to a note of a certain pitch, or loaded springs which have a definite period of vibration. But the resonance will be most perfectly attained in that case in which the motion is effected with the greatest freedom. Now in mechanics, considering the vibration in the common medium—that is, air—it is of comparatively little importance whether one tuning fork be somewhat larger than another, because the losses in the air are not very considerable. One may, of course, enclose a tuning fork in an exhausted vessel and by thus reducing the air resistance to a minimum obtain better resonant action. Still the difference would not be very great. But it would make a great difference if the tuning fork were immersed in mercury. In the electrical vibration it is of enormous importance to arrange the conditions so that the vibration is effected with the greatest freedom. The magnitude of the resonance effect depends, under otherwise equal conditions, on the quantity of electricity set in motion or on the strength of the current driven through the circuit. But the circuit opposes the passage of the currents by reason of its impedance and therefore, to secure the best action it is necessary to reduce the impedance to a minimum. It is impossible to overcome it entirely, but merely in part, for the ohmic resistance cannot be overcome. But when the frequency of the impulses is very great, the flow of the current is practically determined by self-induction. Now self-induction can be overcome by combining it with capacity. If the relation between these is such, that at the frequency used they annul each other, that is, have such values as to satisfy the condition of resonance, and the greatest quantity of electricity is made to flow through the external circuit, then the best result is obtained. It is simpler and safer to join the condenser in series with the self-induction. It is clear that in such

combinations there will be, for a given frequency, and considering only the fundamental vibration, values which will give the best result, with the condenser in shunt to the self-induction coil; of course more such values than with the condenser in series. But practical conditions determine the selection. In the latter case in performing the experiments one may take a small self-induction and a large capacity or a small capacity and a large self-induction, but the latter is preferable, because it is inconvenient to adjust a large capacity by small steps. By taking a coil with a very large self-induction the critical capacity is reduced to a very small value, and the capacity of the coil itself may be sufficient. It is easy, especially by observing certain artifices, to wind a coil through which the impedance will be reduced to the value of the ohmic resistance only; and for any coil there is, of course, a frequency at which the maximum current will be made to pass through the coil. The observation of the relation between self-

Fig. 184

induction, capacity and frequency is becoming important in the operation of alternate current apparatus, such as transformers or motors, because by a judicious determination of the elements the employment of an expensive condenser becomes unnecessary. Thus it is possible to pass through the coils of an alternating current motor under the normal working conditions the required current with a low E. M. F. and do away entirely with the false current, and the larger the motor, the easier such a plan becomes practicable; but it is necessary for this to employ currents of very high potential or high frequency.

In Fig. 184 I. is shown a plan which has been followed in the study of the resonance effects by means of a high frequency alternator. C_1 is a coil of many turns, which is divided into small separate sections for the purpose of adjustment. The final adjustment was made sometimes with a few thin iron wires (though this is not always advisable) or with a closed secondary. The coil

c_1 is connected with one of its ends to the line L from the alternator G and with the other end to one of the plates c of a condenser $c\,c_1$, the plate (c_1) of the latter being connected to a much larger plate P_1. In this manner both capacity and self-induction were adjusted to suit the dynamo frequency.

As regards the rise of potential through resonant action, of course, theoretically, it may amount to anything since it depends on self-induction and resistance and since these may have any value. But in practice one is limited in the selection of these values and besides these, there are other limiting causes. One may start with, say, 1,000 volts and raise the E. M. F. to 50 times that value, but one cannot start with 100,000 and raise it to ten times that value because of the losses in the media which are great, especially if the frequency is high. It should be possible to start with, for instance, two volts from a high or low frequency circuit of a dynamo and raise the E. M. F. to many hundred times that value. Thus coils of the proper dimensions might be connected each with only one of its ends to the mains from a machine of low E. M. F., and though the circuit of the machine would not be closed in the ordinary acceptance of the term, yet the machine might be burned out if a proper resonance effect would be obtained. I have not been able to produce, nor have I observed with currents from a dynamo machine, such great rises of potential. It is possible, if not probable, that with currents obtained from apparatus containing iron the disturbing influence of the latter is the cause that these theoretical possibilities cannot be realized. But if such is the case I attribute it solely to the hysteresis and Foucault current losses in the core. Generally it was necessary to transform upward, when the E. M. F. was very low, and usually an ordinary form of induction coil was employed, but sometimes the arrangement illustrated in Fig. 184 II., has been found to be convenient. In this case a coil C is made in a great many sections, a few of these being used as a primary. In this manner both primary and secondary are adjustable. One end of the coil is connected to the line L_1 from the alternator, and the other line L is connected to the intermediate point of the coil. Such a coil with adjustable primary and secondary will be found also convenient in experiments with the disruptive discharge. When true resonance is obtained the top of the wave must of course be on the free end of the coil as, for instance, at the terminal of the phosphorescence bulb B. This is

easily recognized by observing the potential of a point on the wire or near to the coil.

In connection with resonance effects and the problem of transmission of energy over a single conductor which was previously considered, I would say a few words on a subject which constantly fills my thoughts and which concerns the welfare of all. I mean the transmission of intelligible signals or perhaps even power to any distance without the use of wires. I am becoming daily more convinced of the practicability of the scheme; and though I know full well that the great majority of scientific men will not believe that such results can be practically and immediately realized, yet I think that all consider the developments in recent years by a number of workers to have been such as to encourage thought and experiment in this direction. My conviction has grown so strong, that I no longer look upon this plan of energy or intelligence transmission as a mere theoretical possibility, but as a serious problem in electrical engineering, which must be carried out some day. The idea of transmitting intelligence without wires is the natural outcome of the most recent results of electrical investigations. Some enthusiasts have expressed their belief that telephony to any distance by induction through the air is possible. I cannot stretch my imagination so far, but I do firmly believe that it is practicable to disturb by means of powerful machines the electrostatic condition of the earth and thus transmit intelligible signals and perhaps power. In fact, what is there against the carrying out of such a scheme? We now know that electric vibration may be transmitted through a single conductor. Why then not try to avail ourselves of the earth for this purpose? We need not be frightened by the idea of distance. To the weary wanderer counting the mile-posts the earth may appear very large, but to that happiest of all men, the astronomer, who gazes at the heavens and by their standard judges the magnitude of our globe, it appears very small. And so I think it must seem to the electrician, for when he considers the speed with which an electric disturbance is propagated through the earth all his ideas of distance must completely vanish.

A point of great importance would be first to know what is the capacity of the earth? and what charge does it contain if electrified? Though we have no positive evidence of a charged body existing in space without other oppositely electrified bodies being near, there is a fair probability that the earth is such a body, for

by whatever process it was separated from other bodies—and this is the accepted view of its origin—it must have retained a charge, as occurs in all processes of mechanical separation. If it be a charged body insulated in space its capacity should be extremely small, less than one-thousandth of a farad. But the upper strata of the air are conducting, and so, perhaps, is the medium in free space beyond the atmosphere, and these may contain an opposite charge. Then the capacity might be incomparably greater. In any case it is of the greatest importance to get an idea of what quantity of electricity the earth contains. It is difficult to say whether we shall ever acquire this necessary knowledge, but there is hope that we may, and that is, by means of electrical resonance. If ever we can ascertain at what period the earth's charge, when disturbed, oscillates with respect to an oppositely electrified system or known circuit, we shall know a fact possibly of the greatest importance to the welfare of the human race. I propose to seek for the period by means of an electrical oscillator, or a source of alternating electric currents. One of the terminals of the source would be connected to earth as, for instance, to the city water mains, the other to an insulated body of large surface. It is possible that the outer conducting air strata, or free space, contain an opposite charge and that, together with the earth, they form a condenser of very large capacity. In such case the period of vibration may be very low and an alternating dynamo machine might serve for the purpose of the experiment. I would then transform the current to a potential as high as it would be found possible and connect the ends of the high tension secondary to the ground and to the insulated body. By varying the frequency of the currents and carefully observing the potential of the insulated body and watching for the disturbance at various neighboring points of the earth's surface resonance might be detected. Should, as the majority of scientific men in all probability believe, the period be extremely small, then a dynamo machine would not do and a proper electrical oscillator would have to be produced and perhaps it might not be possible to obtain such rapid vibrations. But whether this be possible or not, and whether the earth contains a charge or not, and whatever may be its period of vibration, it certainly is possible—for of this we have daily evidence—to produce some electrical disturbance sufficiently powerful to be perceptible by suitable instruments at any point of the earth's surface.

Assume that a source of alternating currents s be connected, as in Fig. 185, with one of its terminals to earth (conveniently to the water mains) and with the other to a body of large surface P. When the electric oscillation is set up there will be a movement of electricity in and out of P, and alternating currents will pass through the earth, converging to, or diverging from, the point c where the ground connection is made. In this manner neighboring points on the earth's surface within a certain radius will be disturbed. But the disturbance will diminish with the distance, and the distance at which the effect will still be perceptible will depend on the quantity of electricity set in motion. Since the body P is insulated, in order to displace a considerable quantity, the potential of the source must be excessive, since there would be limitations as to the surface of P. The conditions might be adjusted so that the generator or source s will set up the same electrical movement as though its circuit were closed. Thus it is certainly practicable to impress an electric vibration at least of a certain low period upon the earth by means of proper machinery. At what distance such a vibration might be made perceptible can only be conjectured. I have on another occasion considered the question how the earth might behave to electric disturbances. There is no doubt that, since in such an experiment the electrical density at the surface could be but extremely small considering the size of the earth, the air would not act as a very disturbing factor, and there would be not much energy lost through the action of the air, which would be the case if the density were great. Theoretically, then, it could not require a great amount of energy to produce a disturbance perceptible at great distance, or even all over the surface of the globe. Now, it is quite certain that at any point within a certain radius of the source s a properly adjusted self-induction and capacity device can be set in action by resonance. But not only can this be done, but another source s_1, Fig. 185, similar to s, or any number of such sources, can be set

Fig. 185.

to work in synchronism with the latter, and the vibration thus intensified and spread over a large area, or a flow of electricity produced to or from the source S' if the same be of opposite phase to the source S. I think that beyond doubt it is possible to operate electrical devices in a city through the ground or pipe system by resonance from an electrical oscillator located at a central point. But the practical solution of this problem would be of incomparably smaller benefit to man than the realization of the scheme of transmitting intelligence, or perhaps power, to any distance through the earth or environing medium. If this is at all possible, distance does not mean anything. Proper apparatus must first be produced by means of which the problem can be attacked and I have devoted much thought to this subject. I am firmly convinced that it can be done and hope that we shall live to see it done.

ON THE LIGHT PHENOMENA PRODUCED BY HIGH-FREQUENCY CURRENTS OF HIGH POTENTIAL AND GENERAL REMARKS RELATING TO THE SUBJECT.

Returning now to the light effects which it has been the chief object to investigate, it is thought proper to divide these effects into four classes: 1. Incandescence of a solid. 2. Phosphorescence. 3. Incandescence or phosphorescence of a rarefied gas; and 4. Luminosity produced in a gas at ordinary pressure. The first question is: How are these luminous effects produced? In order to answer this question as satisfactorily as I am able to do in the light of accepted views and with the experience acquired, and to add some interest to this demonstration, I shall dwell here upon a feature which I consider of great importance, inasmuch as it promises, besides, to throw a better light upon the nature of most of the phenomena produced by high-frequency electric currents. I have on other occasions pointed out the great importance of the presence of the rarefied gas, or atomic medium in general, around the conductor through which alternate currents of high frequency are passed, as regards the heating of the conductor by the currents. My experiments, described some time ago, have shown that, the higher the frequency and potential difference of the currents, the more important becomes the rarefied gas in which the conductor is immersed, as a factor of the heating. The potential difference, however, is, as I then pointed out, a more im-

may remain lighted if the plate be interposed, or may even increase in luminosity. The effect depends on the position of the plate and tube relatively to the coil, and may be always easily foretold by *assuming* that conduction takes place from one terminal of the coil to the other. According to the position of the plate, it may either divert from or direct the current to the tube.

In another line of work the writer has in frequent experiments maintained incandescent lamps of 50 or 100 volts burning at any desired candle power with both the terminals of each lamp connected to a stout copper wire of no more than a few feet in length. These experiments seem interesting enough, but they are not more so than the queer experiment of Faraday, which has been revived and made much of by recent investigators, and in which a discharge is made to jump between two points of a bent copper wire. An experiment may be cited here which may seem equally interesting. If a Geissler tube, the terminals of which are joined by a copper wire, be approached to the coil, certainly no one would be prepared to see the tube light up. Curiously enough, it does light up, and, what is more, the wire does not seem to make much difference. Now one is apt to think in the first moment that the impedance of the wire might have something to do with the phenomenon. But this is of course immediately rejected, as for this an enormous frequency would be required. This result, however, seems puzzling only at first; for upon reflection it is quite clear that the wire can make but little difference. It may be explained in more than one way, but it agrees perhaps best with observation to assume that conduction takes place from the terminals of the coil through the space. On this assumption, if the tube with the wire be held in any position, the wire can divert little more than the current which passes through the space occupied by the wire and the metallic terminals of the tube; through the adjacent space the current passes practically undisturbed. For this reason, if the tube be held in any position at right angles to the line joining the binding posts of the coil, the wire makes hardly any difference, but in a position more or less parallel with that line it impairs to a certain extent the brilliancy of the tube and its facility to light up. Numerous other phenomena may be explained on the same assumption. For instance, if the ends of the tube be provided with washers of sufficient size and held in the line joining the terminals of the coil, it will not light up, and then nearly the whole of the current, which would otherwise

practice by combining an electric generator with his oscillator. He pointed out what conditions must be observed in order that the period of vibration of the electrical system might not disturb the mechanical oscillation in such a way as to alter the periodicity, but merely to shorten the stroke. He combines a condenser with a self induction, and gives to the electrical system the same period as that at which the machine itself oscillates, so that both together then fall in step and electrical and mechanical resonance is obtained, and maintained absolutely unvaried.

Next he showed a model of a motor with delicate wheelwork which was driven by these currents at a constant speed, no matter what the air pressure applied was, so that this motor could be employed as a clock. He also showed a clock so constructed that it could be attached to one of the oscillators, and would keep absolutely correct time. Another curious and interesting feature which Mr. Tesla pointed out was that, instead of controlling the motion of the reciprocating piston by means of a spring, so as to obtain isochronous vibration, he was actually able to control the mechanical motion by the natural vibration of the electro-magnetic system, and he said that the case was a very simple one, and was quite analogous to that of a pendulum. Thus, supposing we had a pendulum of great weight, preferably, which would be maintained in vibration by force, periodically applied; now that force, no matter how it might vary, although it would oscillate the pendulum, would have no control over its period.

Mr. Tesla also described a very interesting phenomenon which he illustrated by an experiment. By means of this new apparatus, he is able to produce an alternating current in which the E. M. F. of the impulses in one direction preponderates over that of those in the other, so that there is produced the effect of a direct current. In fact he expressed the hope that these currents would be capable of application in many instances, serving as direct currents. The principle involved in this preponderating E. M. F. he explains in this way: Suppose a conductor is moved into the magnetic field and then suddenly withdrawn. If the current is not retarded, then the work performed will be a mere fractional one; but if the current is retarded, then the magnetic field acts as a spring. Imagine that the motion of the conductor is arrested by the current generated, and that at the instant when it stops to move into the field, there is still the

maximum current flowing in the conductor; then this current will, according to Lenz's law, drive the conductor out of the field again, and if the conductor has no resistance, then it would leave the field with the velocity it entered it. Now it is clear that if, instead of simply depending on the current to drive the conductor out of the field, the mechanically applied force is so timed that it helps the conductor to get out of the field, then it might leave the field with higher velocity than it entered it, and thus one impulse is made to preponderate in E. M. F. over the other.

With a current of this nature, Mr. Tesla energized magnets strongly, and performed many interesting experiments bearing out the fact that one of the current impulses preponderates. Among them was one in which he attached to his oscillator a ring magnet with a small air gap between the poles. This magnet was oscillated up and down 80 times a second. A copper disc, when inserted within the air gap of the ring magnet, was brought into rapid rotation. Mr. Tesla remarked that this experiment also seemed to demonstrate that the lines of flow of current through a metallic mass are disturbed by the presence of a magnet in a manner quite independently of the so-called Hall effect. He showed also a very interesting method of making a connection with the oscillating magnet. This was accomplished by attaching to the magnet small insulated steel rods, and connecting to these rods the ends of the energizing coil. As the magnet was vibrated, stationary nodes were produced in the steel rods, and at these points the terminals of a direct current source were attached. Mr. Tesla also pointed out that one of the uses of currents, such as those produced in his apparatus, would be to select any given one of a number of devices connected to the same circuit by picking out the vibration by resonance. There is indeed little doubt that with Mr. Tesla's devices, harmonic and synchronous telegraphy will receive a fresh impetus, and vast possibilities are again opened up.

Mr. Tesla was very much elated over his latest achievements, and said that he hoped that in the hands of practical, as well as scientific men, the devices described by him would yield important results. He laid special stress on the facility now afforded for investigating the effect of mechanical vibration in all directions, and also showed that he had observed a number of facts in connection with iron cores.

DEFENDANT'S EXHIBIT E-4

THE WORK OF HERTZ

[illegible] the Physical Society of London saw their way to translate and publish a collection of, at any rate, some of these Papers.*

Portrait [illegible].

The portrait (Fig. 1) which I show is not a specially pleasing one. It is from a photograph taken by Mr. Yule, one of the band of foreign students who flocked to Hertz's laboratory at Bonn. It is excellent as a photograph, though it fails to represent Hertz at his best, perhaps because it was not taken till after the pharyngeal trouble had set in, which ultimately carried him off.

In closing these introductory and personal remarks, I should like to say that the enthusiastic admiration for Hertz's spirit and character, felt and expressed by students and workers who came into contact with him, is not easily to be exaggerated. Never was a man more painfully anxious to avoid wounding the susceptibilities of others; and he was accustomed to deprecate the prominence given to him by speakers and writers in this country, lest it might seem to exhalt him unduly above other and older workers among his own sensitive countrymen.

Fig. 1. [illegible]

* [illegible]

1878-79. Wied. Ann. 1880, vol. 10, p. 414. Experiments [illegible] Upper Limit of the Kinetic Energy of Electric Flow.

1880. Inaugural Dissertation (Doctor Thesis). On Induction in Rotating Spheres.

1881. Vol. 13. Wied. Ann. p. 266. On the Distribution of Electricity on the Surface of Moving Conductors.

1881. [illegible] vol. 92, p. 156. On the Contact of Solid Elastic Bodies.

1881. Vol. 14. Wied. Ann. p. 581. Upper Limits for the Kinetic [illegible] of Moving Electricity.

1882. [illegible] Sonderabdruck. On the Contact of Solid Elastic Bodies and on Hardness.

1882. Wied. Ann. vol. 17, p. 177. On the Evaporation of Liquids, especially of Quicksilver, in Air-Free Space, and on the Pressure of Mercury Vapour.

1882. [illegible] *Gesellschaft in Berlin*, p. 18. On a New Hygrometer.

1883. March. [illegible] *Zeitschrift*, p. 125. On the Distribution of Pressure in an Elastic Circular Cylinder.

1883. Wied. Ann. vol. 19, p. 78. On an Appearance accompanying Electric Discharge.

1883. [illegible] 19, p. 782. Experiments on Glow Discharge.

1883. Wied. Ann. vol. 20, p. 279. On the Property of Benzene as an Insulator and as showing Elastic Reaction [illegible].

1883. *Zeitschrift für Instrumentenkunde*. Dynamometric [illegible] Small Resistance and Infinitesimal Self-Induction.

1884. [illegible] *Zeitschrift*, November-December. Graphic Methods [illegible] the Adiabatic Changes of Condition of Moist Air.

1884. [illegible] vol. 22, p. 449. On the Equilibrium of [illegible] Elastic Plates.

1884. [illegible] 23. On the Connection between Maxwell's Electrodynamic Fundamental Equations and those of Opponent Electrodynamics.

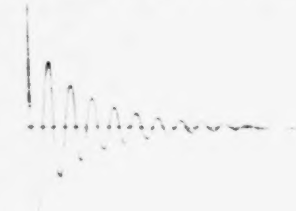
1885. [illegible] vol. 24, p. 114. On the Dimensions of a Magnetic Pole in Different Systems of Units.

1887-1889. Papers incorporated in his book "Ausbreitung der Elektrischen Kraft," translated under the title of "Electric Waves."

1892. Wied. Ann. vol. 45, p. 28. On the Passage of Cathode Rays through Thin Metal Sheets.

Speaking of the other great workers in physics in Germany, [illegible] the sorrow with which we have [illegible] the recent death of Dr. August Kundt, Professor in the University of Berlin, successor of von Helmholtz in that capacity.

When I consented to discourse on the work of Hertz, my intention was to repeat some of his actual experiments, and [illegible] to demonstrate his less known discoveries and observations. [illegible] the fascination exerted upon me by electric oscillation experiments when I, too, was independently working at them in the spring of 1888,* resumed its hold, and my lecture will accordingly [illegible] experimental demonstrations of the outcome of Hertz's work [illegible] than any precise repetition of portions of that work itself.



[illegible]

[illegible]

If the body receiving them has a natural free vibration [illegible] to rest, Fig. 2; then it can respond fully to notes of almost any [illegible]. This is the case with our ears and the tones of my voice. [illegible] must be exceedingly strong before they cease to excite the [illegible].

If, on the other hand, the receiving body has a persistent [illegible] of vibration, continuing in motion long after it is left to itself, like, say, the tuning-fork or bell, for instance, then [illegible] faculty of response exists, but great accuracy of tuning is [illegible] it is to be fully called out; for if the receiver is not [illegible] rately syntonised with the source, it fails more or less completely to respond.

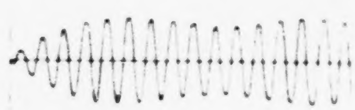


Fig. 4.

Conversely, if the [illegible] is a persistent vibrator, correct [illegible] is essential, or it will destroy at one moment the motion which [illegible] originated the previous moment. Whereas, if it is a [illegible] strongly damped exciter, almost anything will respond [illegible] or equally ill to it.

What I have said of sounding bodies is true of all [illegible] medium competent to transmit waves. Now a [illegible] or a microphone, when spoken to, emits waves into [illegible] this radiant energy is likewise able to set up vibrations [illegible] bodies. But we have no delicate means of [illegible] these electrical or etherial waves, and if they are to [illegible] perceptible effect at a distance, they must be [illegible] speaking tube, prevented from spreading, and concentrated on a distant receiver.

* *Phil. Mag.*, XXVI., pp. 229-230, August, 1888 [illegible] and [illegible] Maxwell's [illegible] See Vol. I., p. 27.

This is the function of the telegraph wire; it is to the ether what a speaking tube is to air. A metal wire in air (*in function*, not in details of analogy) is like a long hollow cavity surrounded by nearly rigid but slightly elastic walls.

Sphere Charge from Electrophorous.

Furthermore, any conductor electrically charged or discharged with sufficient suddenness must emit electrical waves into the ether, because the charge given to it will not settle down instantly, but will surge to and fro several times first, and these surgings or electric oscillations must, according to Maxwell, start waves in the ether, because at the end of each half swing they cause electrostatic, and at the middle of each half swing they cause electromagnetic effects, and the rapid alternation from one of these modes of energy to the other constitutes etherial waves.* If a wire is handy they will run along it, and may be felt a long way off. If no wire exists they will spread out like sound from a bell, or light from a spark, and their intensity will decrease according to the inverse square of the distance.

Maxwell and his followers well knew that there would be such waves; they knew the rate at which they would go, they knew that they would go slower in glass and water than in air, they knew that they would curl round sharp edges, that they would be partly absorbed but mainly reflected by conductors, that if turned back upon themselves they would produce the phenomena of stationary waves, or interference, or nodes and loops; it was known how to calculate the length of such waves, and even how to produce them of any required or predetermined wave-length from 1,000 miles to a foot. Other things were known about them which would take too long to enumerate: any homogeneous insulator would transmit them, would refract or concentrate them if it were of suitable shape, would reflect none of a particular mode of vibration at a certain angle, and so on, and so on.

All this was known, I say, known with varying degrees of confidence, but by some known with as great confidence as, perhaps even more confidence than, is legitimate before the actuality of experimental verification.

Hertz supplied the verification. He inserted suitable conductors in the path of such waves, conductors adapted for the occurrence in them of induced electric oscillations, and to the surprise of everyone, himself doubtless included, he found that the secondary electric surgings thus excited were strong enough to display themselves by minute electric sparks.

Syntonic Leyden Jars.

I shall show this in a form which requires great precision of tuning or syntony, both emitter and receiver being persistently vibrating things giving some 30 or 40 swings before damping has a serious effect. I take two Leyden jars with circuits about a yard in diameter, and situated about two yards apart (Fig. 5). I charge and discharge one jar, and observe that the surgings set up in the other can cause it to overflow if it is syntonised with the first.†

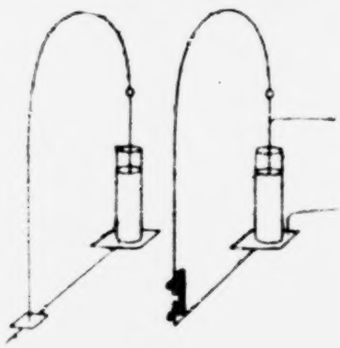


Fig. 5.

A closed circuit such as this is a feeble radiator and a feeble absorber, so it is not adapted for action at a distance. In fact, I doubt whether it will visibly act at a range beyond the $\frac{1}{4}\lambda$ at which true radiation of broken off energy occurs. If the coatings of the jar are separated to a greater distance, so that the dielectric is more exposed, it radiates better; because in true radiation the electrostatic and the magnetic energies are equal, whereas in a ring circuit the magnetic energy greatly predominates. By separating the coats of the jar as far as possible we get a typical Hertz oscillator (Fig. 6), whose dielectric extends out into the room, and this radiates very powerfully.

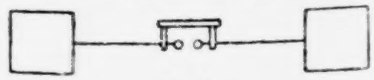


Fig. 6.

Ordinary Size Hertz Vibrator.

In consequence of its radiation of energy, its vibrations are rapidly damped, and it only gives some three or four good strong swings. Hence it follows that it has a wide range of excitation, i.e., it can excite sparks in conductors barely at all in tune with it.

The two conditions, conspicuous energy of radiation and persistent vibration electrically produced, are at present incompatible. Whenever these two conditions coexist, considerable power or activity will, of course, be necessary in the source of energy. At present they only coexist in the sun and other stars in the electric arc and in furnaces.

Two Circular Vibrators sparking in sympathy.

The receiver Hertz used was chiefly a circular resonator, not a good absorber but a persistent vibrator, well adapted for picking up disturbances of precise and measurable wave-length. I find that the circular resonators can act as senders too; here is one exciting quite long sparks in a second one.

Electric Syntony.—That was his discovery, but he did not stop there. He at once proceeded to apply his discovery to the verification of what had already been predicted about the waves, and by laborious and difficult interference experiments he ascertained that the previously calculated length of the waves was thoroughly borne out by fact. These interference experiments in free space are his greatest achievement.

He worked out every detail of the theory splendidly, separately analysing the electric and the magnetic oscillation, using language not always such as we should use now, but himself growing in theoretic insight through the medium of what would have been to most physicists a confusing maze of troublesome facts, and disentangling all their main relations most harmoniously.

Holtz Machine, A and B Sparks; Glass and Quartz Panes in Screen.

While Hertz was observing sparks such as these, the primary or exciting spark and the secondary or excited one, he observed as a bye issue that the secondary spark occurred more easily if the light from the primary fell upon its knobs. He examined this new influence of light in many ways, and showed that although spark light and electric brush light were peculiarly effective any source of light that gave very ultra violet rays produced the same result.*

Wiedemann and Ebert, and a number of experimenters, have repeated and extended this discovery, proving that it is the cathode knob on which illumination takes effect; and Hallwachs made the important observation, which Righi, Stoletow, Branly, and others have extended, that a freshly polished zinc or other oxidisable surface, if charged negatively, is gradually discharged by ultra violet light.

It is easy to fail in reproducing this experimental result if the right conditions are not satisfied; but if they are, it is absurdly easy, and the thing might have been observed nearly a century ago.

(*To be continued.*)

MEETINGS OF SCIENTIFIC SOCIETIES, &c.

TO-DAY (FRIDAY), June 8th.

PHYSICAL SOCIETY.

5 p.m. (1) Discussion of the Paper by W. Baly and Prof. Ramsay "On the Relations of Pressure, Volume, and Temperature of Rarefied Gases." (2) An Exhibition of Photographs of Flames by Capt. Abney.

ROYAL INSTITUTION.

9 p.m. Friday Evening Discourse: "The Newtonian Constant of Gravitation," by C. Vernon Boys, F.R.S.

WEDNESDAY, June 13th.

ROYAL SOCIETY.

Ladies' Conversazione.

*** Particulars of meetings to be held or Papers to be read before Scientific Societies during the coming week should reach us not later than Thursday, 3 p.m.

* Strictly speaking, in the waves themselves there is no lag or difference of phase between the electric and the magnetic vibrations; the difference exists in emitter or absorber, not in the transmitting medium. True radiation of energy does not begin till about a quarter wave-length from the source, and within that distance the initial quarter period difference of phase is obliterated.

† See *Nature*, Vol. XLI., p. 368; or J. J. Thomson's "Recent Researches," p. 395.

* The experiments shown in the lecture was on the lines of those [illegible]," pp. 314 and 340; the con[illegible] depicted in "*Proc. Roy. Soc.*

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absolute values for n and for $-n$, which are equal. It is equal to zero for $n=0$, increases with the increase of n, and for $n = \pm \infty$ tends asymptotically towards the value $\frac{1}{2\pi L}$ as its limit. If, then (Fig. 16), we take as abscissæ the values of n, and as ordinates the absolute values of y, and if we take as origin the point O, and as the positive direction of the axis of n the line O X', we find the line F O F', which has for asymptote the straight line, L L, parallel to the axis of the abscissæ. In order to find $y_1 - y_2$ we take $O O_1 = n$ and $O_1 p_1 = O_1 p_2 = m$; there results $O p_1 = n - m$, $O p_2 = n + m$, whence the ordinates $p_1 P_1$ and $p_2 P_2$ represent y_1 and y_2, and we have at once $y_1 - y_2 = p_1 P_1 - p_2 P_2 = -(p_2 P_2 - p_1 P_1)$.

The mode of variation of this difference appears clear if we draw Q P, M the line symmetric with respect to $O_1 Y_1$ to $Q P_2 F_2$. Now we have $y_1 - y_2 = -P_1 P_2$. We can, if we wish, take this length as ordinate, and thus find, that taking as origin the point O_1, as axis of the ordinates the line $O_1 Y_1$ and as the positive direction of the axis of abscissæ $O_1 X$, $y_1 - y_2$ is represented as a function of m by the curve O_1 P M N.

The sign ($-$) of the value derived from the condition $p_2 P_2 > p_1 P_1$ tells that the flux under consideration rotates towards the left, or in the direction opposed to the movement of the armature. Now this flux, which turns towards the left, produces in the metal of the fixed part of the machine, induced currents on which it then exercises forces tending to draw it from its proper rotation, towards the left. Thence, *vice versâ*, the induced currents in the fixed part of the machine solicit the armature to turn towards the right, in the direction in which it already moves. Whence results that the rotating flux due to the currents in the armature provokes induced currents, which help the rotation, and give place to a couple, which joins to the principal couple of which we spoke in the preceding article. The value of the couple due to the induced currents varies with the variation of m, and increases with the increase of the ordinate $p_1 P$ of the line O_1 M N. It is zero for $m = 0$ and greatest for $m = n$. Owing to it, the total couple acting on the armature instead of being reduced to zero for $m = O_1 A$ (Fig. 15), is not reduced to zero for any value a little larger, a little nearer to n.

Alternating Flux.—The alternating vector resulting from the composition of two vectors rotating in opposite senses, has an amplitude equal to double the smallest of the two component vectors (Art. 4). However, the alternating flux is proportional to

$$\frac{n - m}{\sqrt{r^2 + 4\pi^2 L^2 (n - m)^2}}.$$

It can be zero only for $m = n$.

THE WORK OF HERTZ.*

(*Continued from page 155.*)

Zinc Discharging Negative Electricity in Light; Gold Leaf Electroscope; Glass and Quartz Panes; Quartz Prism.

Take a piece of zinc, clean it with emery paper, connect it to a gold leaf electroscope and expose it to an arc lamp. If charged positively nothing appears to happen, the action is very slow; but a negative charge leaks away in a few seconds if the light is bright. Any source of light rich in ultra-violet rays will do; the light from a spark is perhaps most powerful of all. A pane of glass cuts off all the action, so does atmospheric air in sufficient thickness (at any rate, town air), hence sunlight is not powerful. A pane of quartz transmits the action almost undiminished, but fluor-spar may be more transparent still. Condensing the arc rays with a quartz lens and analysing them with a quartz prism or reflection grating, we find that the most effective part of the light is high up in the ultra-violet, surprisingly far beyond the limits of the visible spectrum* (Figs. 7 and 8).

This is rather a digression, but I have taken some pains to show it properly because of the interest betrayed by Lord Kelvin on this matter, and the caution which he felt about accepting the results of the Continental experimenters too hastily.

It is probably a chemical phenomenon, and I am disposed to express it as a modification of the volta contact effect* with illumination.

Return now to the Hertz vibrator, or Leyden jar with its coatings well separated, so that we can get into its electric as well as its

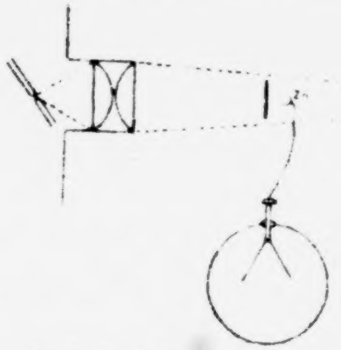

FIG. 7.—Zinc Rod with Glass Screen.

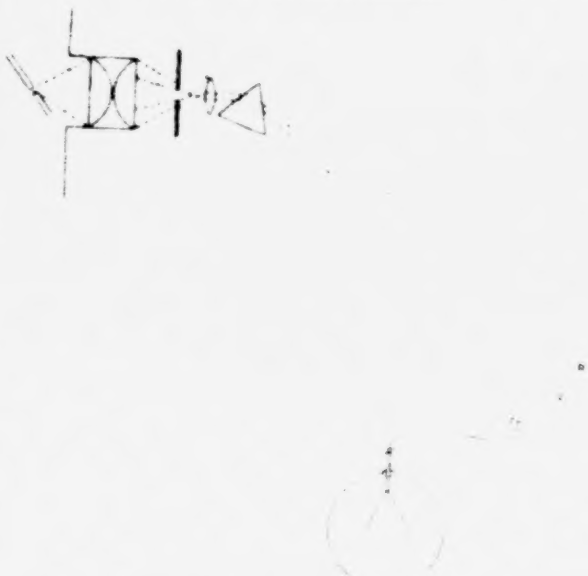

FIG. 8.—Zinc Rod with Ultra-violet Light.

magnetic field. Here is a great one giving waves 30 metres long, radiating while it lasts with an activity of 100 H.P., and making ten million complete electric vibrations per second.

Large Hertz Vibrator in action; Abel's Fuse; Vacuum Tube; Strike an Arc.

Its great radiating power damps it down very rapidly, so that it does not make above two or three swings; but nevertheless, each time it is excited, sparks can be drawn from most of the reasonably elongated conductors in this theatre.

A suitably situated gas leak can be ignited by these induced sparks. An Abel's fuse connecting the water pipes with the gas pipes will blow off; vacuum tubes connected to nothing will glow (this fact has

* A lecture delivered at the Royal Institution on Friday, June 1st, by Prof. Oliver Lodge, F.R.S., ably assisted during both preparation and performance by Mr. Edward E. Robinson.

* While preparing for the lecture it occurred to me to try, if possible, during the lecture itself, some new experiments on the effect of light on negatively charged bits of rock and ice, because if the effect is not limited [illegible] important in connection with atmospheric electricity. [illegible] Mr. [illegible] coated an aluminium plate with an insulating varnish, [illegible] that its charge was able to soak in and out of the varnish during illumination (*Comptes Rendus*, Vol. CX., p. 868, 1890). Now, the mountain [illegible] of a negatively charged earth are exposed to very ultra-violet rays, and the air is a dielectric in which quiet up-carrying and sudden downpour of electricity [illegible] in a manner not very unlike the well-known [illegible] of water vapour; and this perhaps may be the reason, or one of the reasons, why it is not unusual to experience a thunderstorm after a [illegible]. I have now tried these experiments on such geological specimens as were handy, and find that many of them discharge negative electricity under the action of a naked arc, especially from the side of the specimens which was somewhat dusty, but that when wet they discharge much less rapidly, and when positively charged hardly at all. Ice and garden soil discharge negative electrification, too, under ultra-violet illumination, but not so quickly as limestone, mica schist, ferruginous quartz, clay, and some other specimens. Granite [illegible] too well. The ice and soil were tried in their usual moist condition; [illegible] when thoroughly dry, soil discharges quite rapidly. No rock tested was found to discharge as quickly as [illegible] a surface of perfectly bright metal, such as iron, but many discharged much more quickly than [illegible] dull iron, and rather more quickly than when the bright iron surface was thinly oiled or wetted with water. To-day (June 5) I find that the leaves of the geranium discharge positive electrification five times as quickly as negative, under the action of an arc light, and that glass cuts the effect off, while quartz transmits it.

* See Brit. Assoc. Report, 1884, pp. 502-519, or *Phil. Mag.* [illegible], pp. 257-352.

[illegible] familiar to all who have worked with Hertz waves since 1889); electric leads, if anywhere near each other, as they are in some incandescent lamp-holders, may spark across to each other, thus striking an arc and blowing their fuses.

This blowing of fuses by electric radiation frequently happened at Liverpool till the suspensions of the theatre lamps were altered.

The striking of an arc by the little reverberating sparks between two carbon points connected with the 100 volt mains I incidentally [illegible] demonstrate.

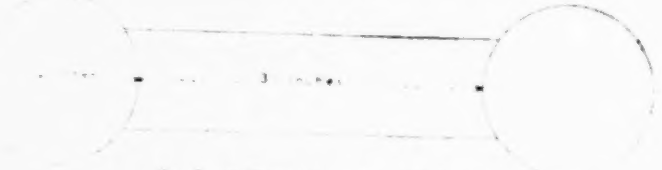

Fig. 9.—A Dumb-bell Form of Radiator.

Fig. 11.—[illegible]

There are some who think that lightning flashes can do none of [illegible] things. They are mistaken.

[illegible] are specimens of various emitters and receivers [illegible] used by different people (see Table). The [illegible] radiator of dumb bell type (Fig. 9), the orthodox [illegible] (Fig. 10), a circular ring (Fig. 11) for interference [illegible] it is but little damped, and a straight wire [illegible] because it is a much better absorber.

[illegible]

Detectors of Radiation.

	Chemical.	Thermal.	Electrical.	Mechanical.	[illegible]
					[illegible]
[illegible]	[illegible] Plate	Thermopile	Spark (Hertz.)	Electrometer (Blyth and Bjerknes.)	[illegible]
Frog's Leg [illegible]	Explosive Gases	Bolometer (Rubens and Ritter.)	Telephone (Air gap and Arc) ([illegible])	Suspended Wires (Hertz and Boys.)	[illegible]
	Photo-electric Cell	Expanding Wire ([illegible])	Vacuum Tube ([illegible])	[illegible]	[illegible]
		Thermal Junction (Klemencic.)	Galvanometer (Fitzgerald.)		
			Air gap and Electroscope (Boltzmann.)		
			Trigger Tube (Warburg and Zehnder.)		

*The cross against the frog's leg indicates that it does not appear really to respond to radiation [illegible] The names against the other things are unimportant, but suggest the persons who applied the detector to electric radiation. [illegible] indicates that its position in the microphonic column may be doubtful.

Beside these are the spheres and ellipsoids (or elliptical plates), which I have mainly used, because they are powerful radiators and absorbers, and because their theory has been worked out by Horace Lamb and J. J. Thomson. Also dumb bells without air [illegible] and many other shapes, the most recent of mine being the [illegible] of a hollow cylinder with sparks at ends of a diameter [illegible] (Fig. 12), being a feeble radiator, but a very persistent vibrator,* and therefore well adapted for interference and diffraction experiments. But, indeed, spheres can be made to vibrate longer than [illegible] by putting them into copper hats or enclosures, in which an aperture of varying size can be made to let the waves out.

Many of these senders will do for receivers too, giving off sparks [illegible] insulated bodies or to earth; but, besides the Hertz type

Fig. 10.—Standard Hertz Radiator.

[illegible] receiver, many other detectors of radiation have been employed. Vacuum tubes can be used, either directly or on the trigger principle as by Zehnder (Fig. [illegible]),† the resonator spark precipitating a discharge from some auxiliary battery or source of energy, and so making a feeble disturbance very visible. Explosives may be used for the [illegible] purpose, either in the form of mixed water gases or in the form of an Abel's fuse. Fitzgerald found that a tremendously sensitive galvanometer could indicate that a feeble spark had passed, by reason of the consequent disturbance of [illegible] equilibrium which settled down again through the galvanometer. This was the method he used in this theatre four years ago. Blyth used a one-sided electrometer, and young Bjerknes has greatly developed this method (Fig. 14), abolishing the need for a spark, and making the electrometer metrical, integrating, and satisfactory. With this detector many measurements have been made at Bonn by Bjerknes, Yule, Barton, and others on waves [illegible] and kept from space dissipation by guiding wires.

Mr. Boys has experimented on the mechanical force [illegible] electrical surgings, and Hertz also made observations of the same kind.

Going back to older methods of detecting electrical radiation we have, most important of all, a discovery made long before man existed, by a creature that developed a sensitive cavity on its [illegible] a creature which never so much as had a name to be remembered by (though, perhaps, we now call it [illegible]). Then, in recent times we recall the photographic [illegible] and the thermopile with [illegible] modification, the radiomicrometer, [illegible] the so-called bolometer or otherwise known Siemens pyrometer, applied to astronomy by Langley, applied to the detection of electric waves in wires by

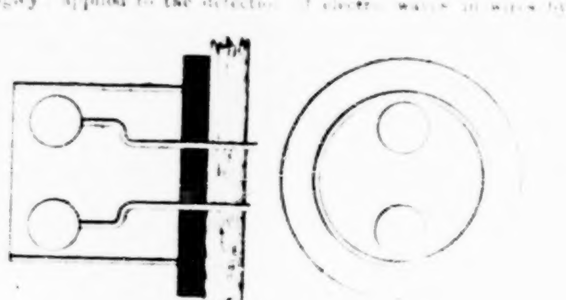

Fig. 12.—Dr. Lodge's Hollow Cylindrical Resonator [illegible] against the [illegible] of a Wooden [illegible]

Rubens and Ritter and Paalzow and Arons. [illegible] was applied to the same purpose by [illegible] and others.

And, before all these, the late Mr. [illegible], made his singularly sensitive [illegible] meter, whereby waves in free space could be detected by the [illegible] of temperature they

[illegible] Thomson, "Recent Researches," 344. † Wied. Ann. XLVII. 47, p. 77.

* Fitzgerald, Nature, [illegible] and Vol. XLIII., p. 172.

† Wied. Ann. [illegible]

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caused in a platinum wire, a kind of early and sensitive form of Cardew voltmeter.

Going back to the physiological method of detecting surgings, Hertz tried the frog's-leg nerve and muscle preparation, which to the steadier types of electrical stimulus is so surpassingly sensitive, and to which we owe the discovery of current electricity. But he failed to get any result. Ritter has succeeded; but, in my experience, failing in the normal and proper result. Working with my colleague Prof. Gotch, at Liverpool, I too have tried the nerve and muscle preparation of the frog (Fig. 15), and we find that an excessively violent stimulus of a rapidly alternating character, if pure and unaccompanied by secondary actions, produces no effect—no stimulating effect, that is, even though the voltage is so high that sparks are ready to jump between the needles in direct contact with the nerve.

All that such oscillations do, if continued, is to produce a temporary paralysis or fatigue of the nerve, so that it is unable to transmit the nerve impulses evoked by other stimuli, from which paralysis it recovers readily enough in course of time.

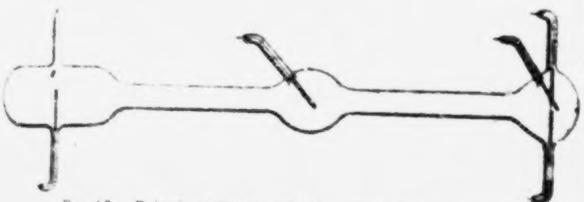


Fig. 13.—Zehnder's Trigger Tube. Half Natural Size.

This has been expected from experiments on human beings, such experiments as Tesla's and those of d'Arsonval. But an entire animal is not at all a satisfactory instrument wherewith to attack the question: its nerves are so embedded in conducting tissues that it may easily be doubted whether the alternating type of stimulus ever reaches them at all. By dissecting out a nerve and muscle from a deceased frog after the historic manner of physiologists, and applying the stimulus direct to the nerve, at the same time as some other well known $\frac{1}{100}$th of a volt stimulus is applied to another part of the same nerve further from the muscle, it can be shown that rapid electric alternations, if entirely unaccompanied by static charge or by resultant algebraic electric transmission, evoke no excitatory response until they are so violent as to give rise to secondary effects such as heat or mechanical shock. Yet, notwithstanding this inaction, they gradually and slowly exert a paralysing or obstructive action on the portion of the nerve to which they are applied, so that the nerve impulse excited by the feeble just perceptible $\frac{1}{100}$th-volt stimulus above is gradually throttled on its way down to the muscle, and remains so throttled for a time varying from a few minutes to an hour after the cessation of the violence.

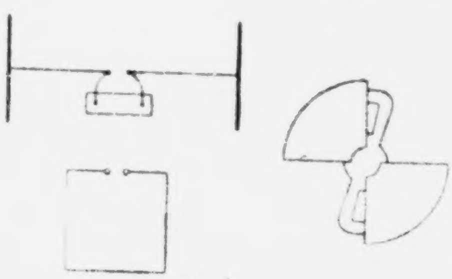


Fig. 14.

I had intended to exhibit this effect, which is very marked and definite, but it is impossible to show everything in the time at my disposal.

Air Gap and Electroscope charged by Glass Rod and discharged by moderately distant Sphere excited by Coil.

Among trigger methods of detecting electric radiation, I have spoken of the Zehnder vacuum tubes; another method is one used by Boltzmann.* A pile of several hundred volts is on the verge of charging an electroscope through an air gap just too wide to break down. Very slight electric surgings precipitate the discharge across the gap, and the leaves diverge. I show this in a modified and simple form. On the cap of an electroscope is placed a highly-polished knob or rounded end connected to the sole, and just not touching the cap (Fig. 16). Such an electroscope overflows suddenly and completely with any gentle rise of potential. Bring excited glass near it, the leaves diverge gradually and then suddenly collapse, because the air space snaps; remove the glass, and they rediverge with negative electricity; the knob above the cap being then charged positively, and to the verge of sparking. In this condition any electrical waves, collected if weak by a foot or so of wire projecting from the cap, will discharge the electroscope by exciting surgings in the wire, and so breaking down the air-gap. The chief interest about this experiment seems to me the extremely definite dielectric strength of so infinitesimal an air space. Moreover, it is a detector for Hertz waves that might have been used last century; it might have been used by Benjamin Franklin.

For to excite them no coil or anything complicated is necessary; it is sufficient to flick a metal sphere or cylinder with a silk handkerchief and then discharge it with a well-polished knob. If it is not well polished the discharge is comparatively gradual, and the vibrations are weak; the more polished are the sides of an air-gap the more sudden is the collapse and the more vigorous the consequent radiation, especially the radiation of high frequency, the higher harmonics of the disturbance.

For delicate experiments it is sometimes well to repolish the knobs every hour or so. For metrical experiments it is often

Fig. 15.—Experiment of Gotch and Lodge on the physiological effect of rapid pure electric alternations. Nerve and muscle preparation, with fine needles or else non-polarisable electrodes applied to the nerve. C and D are the terminals of a rapidly alternating electric current from a conductor at zero potential, while A and B are the terminals of an ordinary very weak galvanic or induction coil stimulus only just sufficient to make the muscle twitch.

better to let the knobs get into a less efficient but more permanent state. This is true of all senders or radiators. For the generation of the, so to speak, "infra red" Hertz waves any knobs will do, but to generate the "ultra violet" high polish is essential.

Microphonic Detectors.

Receivers or detectors, which for the present I temporarily call microphonic, are liable to respond best to the more rapid vibrations. Their sensitiveness is to me surprising, though of course it does not approach the sensitiveness of the eye; at the same time, I am by no means sure that the eye differs from them in kind. It is these detectors that I wish specially to bring to your notice.

Prof. Minchin, whose long and patient work in connection with photo-electricity is now becoming known, and who has devised an instrument more sensitive to radiation than even Boys' radiomicrometer, in that it responds to the radiation of a star while the radiomicrometer does not, found some years ago that some of his slight excitable cells lost their sensitiveness capriciously on tap-

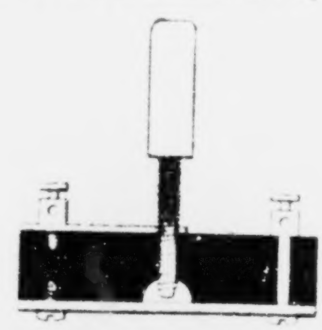


Fig. 16.—Air gap for Electroscope. Natural Size.

ping, and later he found that they frequently regained it again while Mr. Gregory's Hertz-wave experiments were going on in the same room.

These "impulsion cells," as he terms them, are troublesome things for ordinary persons to make and work with—at least I have never presumed to try—but in Mr. Minchin's hands they are surprisingly sensitive to electric waves.*

The sensitiveness of selenium to light is known to everyone, and Mr. Shelford Bidwell has made experiments on the variations of conductivity exhibited by a mixture of sulphur and carbon.

Nearly four years ago M. Edouard Branly found that a burnished coat of porphyrised copper spread on glass diminished its resistance enormously, from some millions to some hundreds of ohms when it was exposed to the neighbourhood, even the distant neighbourhood, of Leyden jars or coil sparks. He likewise found that a tube of metallic filings behaved similarly, but that this recovered its original resistance on shaking. Mr. Croft exhibited this fact

* Wied. Ann., XL., p. 399.

* Phil. Mag., Vol. XXXI., p. 223.

...at the Physical Society. Branly also makes pastes and ... of filings in Canada balsam and in sulphur and found ... likewise sensitive.*

With me the matter arose somewhat differently, as an outcome of the air-gap detector employed with an electroscope by Boltzmann. For I had observed in 1889 that two knobs sufficiently close together, far too close to stand any voltage such as an electroscope can show, would, when a spark passed between them, actually cohere; conducting an ordinary bell ringing current if a single voltaic cell was in circuit; and, if there were no such cell, exhibiting an electromotive force of their own sufficient to disturb a low resistance galvanometer vigorously, and sometimes requiring a faintly perceptible amount of force to detach them. The experiment was described to the Institution of Electrical Engineers,† and Prof. Hughes said he had observed the same thing.

[illegible], responding to Feeble Stimuli; Small Sphere Oscillator; Distant Sphere Electrophorus.

Well, this arrangement, which I call a coherer, is the most astonishingly sensitive detector of Hertz waves. It differs from the ordinary air gap in that the insulating film is not really insulating; the

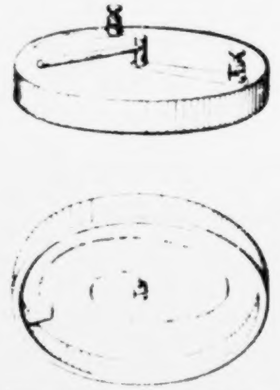


Fig. 17.—Wire Coherer, consisting of a spiral of fine iron wire mounted on adjustable spindle and an aluminium plate. When the lever is [illegible] against a stop not shown in the illustration the tip of the wire presses very gently against the aluminium plate.

film breaks down not only much more easily, but also in a less discontinuous and more permanent manner than an air gap. A tube of filings, being a series of bad contacts, clearly works on the same plan; and though a tube of filings is by no means so sensitive, yet it is in many respects easier to work with, and, except for very feeble stimuli, is more metrical. If the filings used are coarse, say turnings or borings, the tube approximates to a single coherer; if fine, it has a larger range of sensibility. In every case what these receivers feel are sudden jerks of current; smooth

Fig. 18.—Iron Borings Coherer, one-third natural size.

sinusoidal variations are ineffective. They seem to me to respond best to waves a few inches long, but doubtless that is determined chiefly by the dimensions of some conductor with which they happen to be associated (Figs. 17, 18, and 19, [illegible]).

[illegible] Responsive to Sparks, to Electrophorus, to Spark from Gold-leaf Electroscope.

I picture to myself the action as follows: Suppose two fairly clean pieces of metal in light contact—say two pieces of iron—connected to a single voltaic cell; a film of what may be called oxide intervenes between the surfaces, so that only an insignificant current is allowed to pass, because a volt or two is insufficient to break down the insulating film except perhaps at one or two atoms. If the film is not permitted to conduct at all, it is not very sensitive. The most sensitive condition is attained when an infinitesimal current passes, strong enough just to show on a moderate galvanometer.

Now let the slightest surging occur, say by reason of a sphere being charged and discharged at a distance of forty yards, the film at once breaks down—perhaps not completely, but in proportion to the intensity—but permanently. As I imagine, more molecules get within each other's range, incipient cohesion sets in, and the momentary electric quiver acts as it were as a flux. It is a singular variety of electric welding. A stronger stimulus enables more molecules to hold on; the process is surprisingly metrical; and, so far as I roughly know at present, the change of resistance is proportional to the energy of the electric radiation from a source of given frequency.

It is to be specially noted that the battery current is not needed to effect the cohesion, only to demonstrate it. The battery can be applied after the spark has occurred, and the resistance will be found changed as much as if the battery had been on all the time.

The incipient cohesion electrically caused can be mechanically destroyed. Sound vibrations, or any other feeble mechanical disturbances, such as scratches or taps, are well adapted to restore the contact to its original high-resistance sensitive condition. The more feeble the electrical disturbance the slighter is the corresponding mechanical stimulus needed for restoration. When working with the radiating sphere (Fig. 19) at a distance of forty yards out of window, I could not for this reason shout to my assistant, to cause him to press the key of the coil and make a spark, but I showed him a duster instead, this being a silent signal which had no disturbing effect on the coherer or tube of filings. I mention 40 yards because that was one of the first outdoor experiments; but I should think that something more like half a mile was nearer the limit of sensitiveness. However, this is a rash statement not at present verified. At 40 yards the exciting spark could be distinctly heard, and it was interesting to watch the spot of light begin its long excursion and actually travel a distance of 2in. or 3in. before the sound arrived.

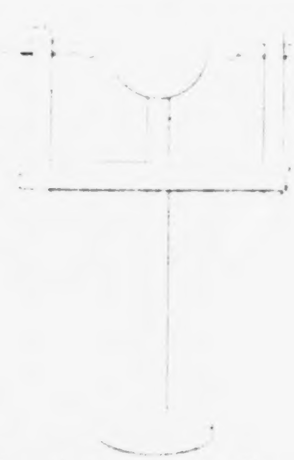


Fig. 19.—Radiator used in the library of the Royal Institution, exciting the Coherer (Fig. 18) on the lecture table in the theatre.

This experiment proved definitely enough that the effect was one travelled quicker than sound, and disposed completely of any sceptical doubts as to the sound waves being, perhaps, the real cause of the phenomenon.

Invariably, when the receiver is in good condition, sound or other mechanical disturbance acts one way, viz., in the direction of increasing resistance, while electrical radiation or sparks act the other way, decreasing it.‡ While getting the receiver into condition, or when it is getting out of order, vibrations and sometimes electric discharges act irregularly, and an occasional good shaking does the filings good. I have taken rough measurements of the resistance by the simple process of restoring the original galvanometer deflection by adding or removing resistance coils. A half-inch tube 8in. long, of selected iron turnings, had a resistance of 2,500 ohms in the sensitive state. A feeble stimulus, caused by a distant electrophorus spark, brought it down 400 ohms. A rather stronger one reduced it by 800 and 900, while a trace of spark given to a point of the circuit itself, ran it down 1,400 ohms.

This is only to give an idea of the quantities. I have not yet done any seriously metrical experiments.

From the wall diagram which summarises the various detectors, and which were prepared a month or so ago, I see I have omitted selenium, a substance which in certain states is well known to behave to visible light as those other microphonic detectors behave to Hertz waves.

And I want to suggest that quite possibly the sensitiveness of the eye is of the same kind. As I am not a physiologist I cannot be seriously blamed for making wild and hazardous speculations in that region. I therefore wish to guess that some part of the retina is an electrical organ, say like that of some fishes, maintaining an electromotive force which is prevented from stimulating the nerves

* Branly, Comptes Rendus, Vol. CXI., p. 785; and Vol. CXII., p. 90.

† Journal Institution of Electrical Engineers, 1890, Vol. XIX., pp. 352-4.

‡ "Lightning Conductors and Lightning Guards" (Whittaker), pp. 382-3.

solely by an intervening layer of badly conducting material, or of conducting material with gaps in it; but that when light falls upon the retina these gaps become more or less conducting, and the nerves are stimulated.

I do not feel clear which part is taken by the rods and cones, and which part by the pigment cells; I must not try to make the hypothesis too definite at present.

If I had to make a demonstration model of the eye on these lines, I should arrange a little battery to excite a frog's nerve and muscle preparation through a circuit completed all except a layer of filings or a single bad contact. Such an arrangement would respond to Hertz waves. Or, if I wanted actual light to act instead of grosser waves, I would use a layer of selenium.

But the bad contact and the Hertz waves are the most instructive, because we do not at present really know what the selenium is doing, any more than what the retina is doing.

And observe that (to my surprise, I confess) the rough outline of a theory of vision thus suggested is in accordance with some of the principal views of the physiologist Hering. The sensation of light is due to the electrical stimulus; the sensation of black is due to the mechanical or tapping back stimulus. Darkness is physiologically not the mere cessation of light. Both are positive sensations, and both stimuli are necessary; for until the filings are tapped back vision is persistent. In the eye model, the period of mechanical tremor should be, say, $\frac{1}{10}$th second, so as to give the right amount of persistence of impression.

No doubt in the eye the tapping back is done automatically by the tissues, so that it is always ready for a new impression, until fatigued. And by mounting an electric bell or other vibrator on the same board as a tube of filings, it is possible to arrange so that a feeble electric stimulus shall produce a feeble steady effect, a stronger stimulus a stronger effect, and so on, the tremor asserting its predominance, and bringing the spot back whenever the electric stimulus ceases.

An electric bell thus close to the tube is, perhaps, not the best vibrator; clockwork might do better, because the bell contains in itself a jerky current, which produces one effect, and a mechanical vibration, which produces an opposite effect; hence the spot of light can hardly keep still! By lessening the vibration—say, by detaching the bell from actual contact with the board, the electric jerks of the intermittent current drive the spot violently up the scale; mechanical tremor brings it down again.

You observe that the eye on this hypothesis is, in electrometer language, heterostatic. The energy of vision is supplied by the organism; the light only pulls a trigger. Whereas the organ of hearing is idiostatic. I might draw further analogies, about the effect of blows or disorder causing irregular conduction and stimulation of the galvanometer in the one instrument, of the brain cells in the other.

A handy portable exciter of electric waves is one of the ordinary hand electric gas lighters, containing a small revolving doubler—or an inductive or replenishing machine. A coherer can feel a gas lighter across a lecture theatre. Minchin often used them for stimulating his impulsion cells. I find that when held near they act a little before the spark occurs, plainly because of the little incipient sparks at the brushes or tinfoil contacts made. A Voss machine acts similarly, giving a small deflection while working up before it sparks. And notice here that our model eye has a well defined range of vision. It cannot see waves too long for it.

(*To be concluded.*)

ELECTRICAL TRADES SECTION.

The members of the Electrical Trade Section of the London Chamber of Commerce met in the afternoon of Thursday, June 7th, at the offices, Botolph House, Eastcheap, under the presidency of Major Flood Page.

After the usual preliminaries were disposed of, the CHAIRMAN said that the members would remember that when they did him the honour of appointing him to the chair he accepted the office on condition that the appointment should be for only two years. The subject was discussed pretty freely at the time, and they came to the conclusion that it would be far better that they should have a change of Chairman every two years. For that period he had presided over the Section, and he now took the opportunity of thanking them for the kindness and forbearance with which they had treated him during the time he had held that honourable position. He had been, more or less, in bad health the whole time, and had not been so active, perhaps, as he might otherwise have been. He believed that it now became his privilege to nominate his successor, and he had great pleasure in proposing that Mr. Emile Garcke should be elected to the office.

Mr. SELLON seconded the motion, which was agreed to unanimously.

Mr. GARCKE, having taken the chair, said that while thanking them for the confidence which they reposed in him by placing him in that responsible position, he felt that he occupied it under the great disadvantage of its having been filled first by Mr. Crompton and then by Major Flood Page. He could but say that he would do his best to perform his duties to the satisfaction of the members. He would like to refer to the very valuable services rendered to the Section by Major Flood Page during his period of office, and to propose a vote of thanks to him for his services. Although that gentleman had not enjoyed the best of health, they must all recognise that he had devoted a great deal of time to the interests of the Section, with the result that they had been enabled to carry out some very important business matters in which they were all interested, such as the subject of overhead wires and various other questions which had to go before the Board of Trade, in connection with which Major Flood Page had rendered very valuable service.

A MEMBER briefly seconded the motion, which was cordially passed.

Major FLOOD PAGE, in expressing his acknowledgment, said that he would be still able to be of some little use to the Section, because the Council had done him the honour of electing him to be a permanent member of that body, and therefore, in addition to the fact that Mr. Garcke, as Chairman of the Section, would be entitled to attend the meetings of the Council, he (Major Flood Page) would always be there to act upon any suggestion which Mr. Garcke might recommend.

On the motion of the CHAIRMAN, seconded by Mr. SYDNEY MORSE, Mr. Siemens was elected Deputy-Chairman.

After a short discussion, a committee was formed to watch the interests of the Section in connection with the rating of electric works, and a letter was read on the subject of the Locomotive Act from the Board of Trade, intimating that the representations of the Section on the question of their amendment had been brought to the notice of the Home Office.

The consideration of the provisions of the Electric Lighting Act with regard to alleged nuisances was left in the hands of the same committee.

On the suggestion of the CHAIRMAN, seconded by Mr. M[illegible] and supported by Mr. SELLON, it was decided to circularise the various departments of the electrical industry, urging upon them the desirability of supporting the Section in promoting the interests appertaining to each.

The proceedings then ended.

AMERICAN NOTES.

(FROM OUR OWN CORRESPONDENT.)

NEW YORK, *June 2*, 1894.

New Telephone Rates.—The local New York City Telephone Company on June 1st introduced a new system of charges for telephone service, based upon the number of messages sent by a subscriber. All lines will be metallic circuits, and the subscriber sending messages of not less than 1,000, nor over 2,000 annually, may elect if he will have a line for his sole use or share one with another subscriber. The lowest annual rate, $100, is for "two party" lines only and 700 messages, the charge for additional messages being $15 per 100. The lowest rate for a "direct" line is $150 per annum, 1,000 messages being the limit, the charge for those in excess of that number being $12 per 100. A "two party" line for this service costs [illegible] less per annum. For 2,000 messages per annum the charge for a "direct" line is $220, and for a "two party" line [illegible], excess messages being $8 per 100. For more than [illegible] messages "direct" lines only can be used, and the rate will be $5 per 100, with $7 per 100 for excess messages.

Central Stations in Massachusetts.—A recent report of the Board of the Gas and Electric Light Commissioners of the Commonwealth of Massachusetts for 1893 shows [illegible] the last year, out of [illegible] central electric lighting stations [illegible] State 28 paid dividends, 20 paid [illegible] earn expenses. Of the $[illegible] paid [illegible] stations paid $[illegible], and the several [illegible] the greater part of the remainder [illegible] those of Boston, paid 8 per cent. [illegible] per cent. and two 5 per cent. The [illegible] companies were returned at $[illegible] surplus of $[illegible], and [illegible]

Of course, if an alternating current supply is available, and a suitable voltmeter, the method may be modified by putting the voltmeter in place of the galvanometer and using alternating current in the primary P. The voltmeter would have to be of high resistance, or an electrostatic one.

Without a galvanometer at all, a very rough test may be made by simply placing a compass needle at the centre of the coil, and observing its deflections when one pole of a battery (with high resistance in circuit) is connected to the bobbin, whilst the other pole is joined successively to the two free ends of the coil.

THE WORK OF HERTZ.*

(Concluded from page 190.)

[illegible] Sparks not exciting Tube except by help of a polished Knob.

The powerful disturbance caused by the violent flashes of a Wimshurst or Voss machine it is blind to. If the knobs of the machine are well polished it will respond to some high harmonics, due to the vibrations in the terminal rods, and these are the vibrations to which it responds when excited by a coil. The coil should have knobs instead of points. Sparks from points or dirty knobs hardly excite the coherer at all. But hold a well polished sphere or third knob between even the dirty knobs of a Voss machine, and the coherer responds at once to the surgings got up in it.

Feeble short sparks again are often more powerful exciters than are strong long ones. I suppose because they are more sudden.

This is instructively shown with an electrophorus lid. Spark it to a knuckle, and it does very little. Spark it to a knob and it works well. But now spark it to an insulated sphere, there is some effect. Discharge the sphere, and take a second spark, without recharging the lid. Do this several times, and at last, when the spark is inaudible, invisible, and otherwise imperceptible, the coherer some yards away responds more violently than ever, and the spot of light rushes from the scale.

If a coherer be attached by a side wire to the gas pipes, and an electrophorus spark be given to either the gas pipes or the water pipes or even to the hot-water system in another room of the building, the coherer responds.

In fact, when thus connected to gas pipes, one day when I tried it, the spot of light could hardly keep five seconds still. Whether there was a distant thunderstorm, or whether it was only picking up telegraphic jerks, I do not know. The jerk of turning on or off an extra Swan lamp can affect it when sensitive. I hope to try for long wave radiation from the sun, filtering out the ordinary well-known waves by a black board or other sufficiently opaque substance.

We can easily see the distance [illegible] to a distant source of radiation now, viz., to a [illegible] placed in the library between [illegible] knobs.

Also I exhibit a small complete detector made by my assistant, Mr. Davies, which is quite portable and easily set up. The essentials are all in a copper cylinder three inches by two. A bit of wire a few inches long, pegged into it, helps it to collect waves. It is just conceivable that at some distant date, say by dint of inserting gold wires or powder in the retina, we may be enabled to see waves which at present we are blind to.

Observe how simple the production and detection of Hertz waves are now. An electrophorus or a frictional machine serves to excite them, a voltaic cell, a rough galvanometer, and a bad contact serves to detect them. Indeed, they might have been observed at the beginning of the century, before galvanometers were known. A frog's leg or an iodide of starch paper would do almost as well.

A bad contact was at one time regarded as a simple nuisance because of the singularly uncertain and capricious character of the current transmitted by it. Hughes observed its sensitiveness to sound waves, and it became the microphone. Now it turns out to be sensitive to electric waves if it be made of any oxidisable metal (not of carbon), and we have an instrument which might be called a micro something, but which, as it appears to act by cohesion, I call at present a coherer. Perhaps some of the capriciousness of an anathematised bad contact was sometimes due to the fact that it was responding to stray electric radiation.

The breaking down of cohesion by mechanical tremour is an ancient process, observed on a large scale by engineers in railway axles and girders; indeed, the cutting of small girders by persistent blows of hammer and chisel reminded me the other day of the tapping back of our cohering surfaces after they have been exposed to the welding effect of the electric jerk.

If a coherer is shut up in a complete metal enclosure, we cannot get at it, but if wires are led from it to an outside ordinary galvanometer, it remains nearly as sensitive as it was before (nearly, not quite), for the circuit picks up the waves and they run down the insulated wires into the closed box. To screen it effectively, it is necessary to enclose battery and galvanometer and every bit of wire connection; the only thing that may be left outside is the needle of the galvanometer. Accordingly, here we have a complete arrangement of battery and coil and coherer, all shut up in a copper box. The coil is fixed against the side of the box at such height that it can act conveniently on an outside suspended compass needle. The slow action of the coil has no difficulty in getting through copper, as everyone knows; only a perfect conductor could screen off that, but the Hertz waves are effectively kept out by sheet copper.

It must be said, however, that the box must be exceedingly well closed for the screening to be perfect. The very narrowest chink permits their entrance, and at one time I thought I should have to solder a lid on before they could be kept entirely out. Clamping a copper lid on to a flange in six places was not enough. But by the use of pads of tinfoil, chinks can be avoided, and the inside of the box becomes then electrically dark.

If even an inch of the circuit protrudes, it at once becomes slightly sensitive again; and if a single branch wire protrudes through the box, provided it is insulated where it passes through, the waves will utilise it as a speaking tube, and run blithely in. And this whether the wire be connected to anything inside or not, though it acts more strongly when connected.

If wires are to be taken out of the box to a coherer in some other enclosure, they must be enclosed in a metal tube, and this tube must be well connected with the metal of both enclosures, if nothing is to get in but what is wanted.

Similarly, when definite radiation is desired, it is well to put the radiator in a copper hat, open in only one direction. And in order to guard against reflected and collateral surgings running along the wires which pass outside to the coil and battery, as they are liable to do, I am accustomed to put all these things in a packing case lined with tinfoil, to the outside of which the sending hat is fixed, and to pull the key of the primary exciting circuit by a string from outside.

With reference to the reflecting power of different substances it may be interesting to give the following numbers, showing the motion of the spot of light when 8in. waves were reflected into the copper hat, the angle of incidence being about 45deg., by the following mirrors:—

Sheet of window glass	0 or at most 1 division
Human body	7 divisions
Drawing board	12
Towel soaked with tap water	12
Tin paper (lead?)	40
Dutch metal paper	70
Tinfoil	80
Sheet copper	100 and up [illegible]

Even then, with the lid of the hat well clamped on, something gets out, but it is not enough to cause serious disturbance of qualitative results. The sender must evidently be thought of as emitting a momentary blaze of light which escapes through every chink. Or, indeed, since the waves are some inches long, the difficulty of keeping them out of an enclosure may be likened to the difficulty of excluding sound; though the difficulty is not quite so great as that, since a reasonable thickness of metal is really opaque. I fancied once or twice I detected a trace of transparency in such metal sheets as ordinary tinplate, but unnoticed chinks elsewhere may have deceived me. It is a thing easy to make sure of as soon as I have more time.

One thing in this connection is noticeable, and that is how little radiation gets either in or out of a small round hole. A narrow long chink in the receiver box lets in a lot; a round hole the size of a shilling lets in hardly any, unless, indeed, a bit of insulated wire protrudes through it like a collecting ear trumpet.

It may be asked how the waves get out of the metal tube of an electric gas lighter. But they do not; they get out through the handle, which, being of ebonite, is transparent. Wrap up the handle tightly in tinfoil, and a gas lighter is powerless.

Optical Experiments.

And now in conclusion I will show some of the ordinary optical experiments with Hertz waves, using as source either one of two devices; either a 6in. sphere with sparks to ends of a diameter (Fig. 20), an arrangement which emits 9in. waves, but of so dead beat a character that it is wise to enclose it in a copper hat to prolong them, and send them out in the desired direction; or else a 2in. hollow cylinder with spark knobs at ends of an internal diameter. This last emits 3in. waves of a very fairly persistent character, but with nothing like the intensity of one of the outside radiators.

As receiver there is no need to use anything sensitive, so I employ a glass tube full of coarse iron filings, put at the back of a copper hat with its mouth turned well askew to the source.

* A lecture delivered at the Royal Institution on Friday, June 1st, by Prof. Oliver Lodge, F.R.S., ably assisted during both preparation and performance by Mr. Edward E. Robinson.

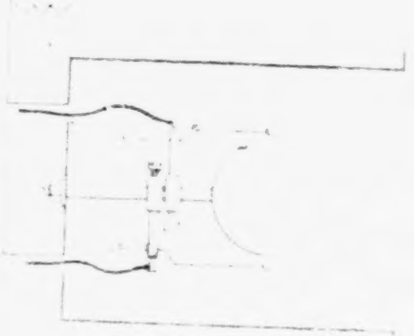
which is put outside the door at a distance of some yards, so that only a little direct radiation can reach the tube. Sometimes the tube is put lengthways in the hat instead of crossways, which makes it less sensitive, and has also the advantage of doing away with the polarising or rather analysing power of a crossway tube.

The radiation from the sphere is still too strong, but it can be stopped down by a diaphragm plate with holes in it of varying size clamped on the sending hat.

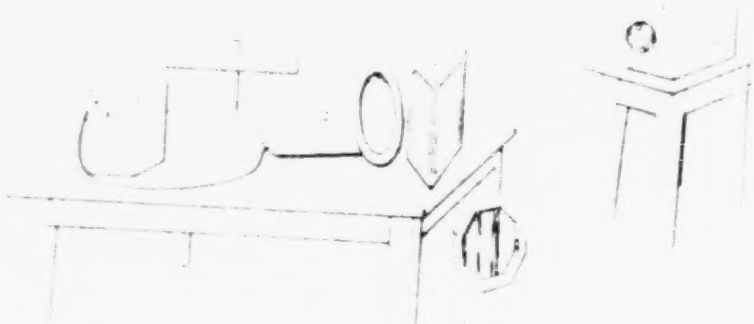
Having thus reduced the excursion of the spot of light to a foot or so, a metal plate is held as reflector, and at once the spot travels a couple of yards. A wet cloth reflects something, but a thin glass plate, if dry, reflects next to nothing, being, as is well known, too thin to give anything but "the black spot." I have fancied that it reflects something of the 3in. waves.

Refracting Prism and Lens.

A block of paraffin about a cubic foot in volume is cast into the shape of a prism with angles 75deg., 60deg., and 45deg. Using the large angle, the rays are refracted into the receiving hat (Fig. [illegible]), and produce an effect much larger than when the prism is removed.



[illegible] 2. [illegible] Radiator [illegible] [illegible] Copper Hat [illegible] [illegible] Wooden Box [illegible] [illegible] Tubes not shown.



[illegible] 3. [illegible]

An ordinary 9in. glass lens is next placed near the source, and by means of the light of a taper it is focussed between source and receiver. The lens is seen to increase the effect.

[illegible] Zone plate.

The lens helps us to set correctly an 18in. circular copper disc in position for showing the bright diffraction spot. Removing the disc the effect is much the same as when it was present. Add the lens and the effect is greater. With a diffraction grating of copper strips 2in. broad and 2in. apart, I have not yet succeeded in getting good results. It is difficult to get sharp nodes and interference effects with these sensitive detectors in a room. I expect to do better when I can try out of doors away from so many reflecting surfaces; indoors it is like trying delicate optical experiments in a small whitewashed chamber well supplied with looking glasses; nor have I ever succeeded in getting clear concentration with this zone plate having Newton rings fixed to it in tinfoil. But really there is nothing of much interest now in diffraction effects except the demonstration of the waves and the measure of their length. There was immense interest in Hertz's time, because then the wave character of the radiation had to be proved, but every possible kind of wave must give interference and diffraction effects, and their theory is, so to say, worked out. More interest attaches to polarisation, double refraction, and dispersion experiments.

Polarising and Analysing Grids.

Polarisation experiments are easy enough. Radiation from a sphere is already strongly polarised, and the tube acts as a partial analyser, responding much more vigorously when its length is parallel to the line of sparks than when they are crossed; but a convenient extra polariser is a grid of wires something like what was used by Hertz only on a much smaller scale; say an 18in. octagonal frame of copper strip with a harp of parallel copper wires (see Fig. 2). The spark line of the radiator being set at 45deg., a vertical grid placed over receiver reduces the deflection to about one half, and a crossed grid over the source reduces it to nearly nothing. Rotating either grid a little rapidly increases the effect, which becomes a maximum when they are parallel. The interposition of a third grid, with its wires at 45deg. between two crossed [illegible] restores some of the obliterated effect.

Radiation reflected from a grid is strongly polarised [illegible] normal, of course, to that of the radiation which [illegible] it. They are thus analogous in their effect to Nicols, or [illegible] of plates.

The electric vibrations which get through these grids are at right angles to the wires. Vibrations parallel to the wires are [illegible] or absorbed.

Reflecting Paraffin Surface.

To demonstrate that the so-called plane of polarisation [illegible] radiation transmitted by a grid is at right angles to the [illegible] vibration,* i.e., that when light is reflected from the boundary [illegible] transparent substance at the polarising angle the electric [illegible] of the reflected beam are perpendicular to the plane of [illegible] I use the same paraffin prism as before; but this time I [illegible] largest face as a reflector, and set it at something near [illegible] polarising angle. When the line of wires is parallel to the plane of incidence, in which case the electric vibrations are perpendicular to the plane of incidence, plenty of radiation is reflected by the paraffin face. Turning the grid so that the electric vibrations [illegible] the plane of incidence, we find that the paraffin surface [illegible] proper angle is able to reflect hardly anything. [illegible] the vibrations contemplated by Fresnel are the [illegible] those dealt with by MacCullagh are the magnetic [illegible]

Thus are some of the simplest [illegible] to the wayfaring man.

A NEW PHENOMENON OBSERVED IN THE PASSAGE OF ELECTRICITY THROUGH BADLY CONDUCTING LIQUIDS.

BY O. LEHMANN.

During the electrolysis of good liquid conductors the [illegible] known to be confined to the proximity of the electrodes. [illegible] as I know, no changes have hitherto been observed [illegible] of badly conducting liquids [illegible] and electric [illegible] On the other hand, I have [illegible] of electricity through various badly conducting [illegible] of aniline dyes, to be attended by changes [illegible] continuously from the electrodes to the centre, [illegible] formation of a precipitate in the middle [illegible] between the electrodes. The phenomena are [illegible] by means of a microscope and an arrangement [illegible] scribed.

If, for instance, a current of about 20 volts pressure [illegible] through an aqueous solution of Congo red, a [illegible] halo is formed round both electrodes of a beautiful blue [illegible] the anode and somewhat paler than the rest of the solution [illegible] cathode, but divided off from it by a darker boundary (Fig. [illegible]

* *Cf.* Trouton in *Nature*, Vol. XXXIX., p. 393, and [illegible] experiments by Mr. Trouton, Vol. XL., p. [illegible]

[illegible] *Wiedemann's Annalen*, Vol. LII., No. [illegible] 1894.

[illegible] Lehmann, *Molecular*[illegible] 1889.

The Art of Soldering. By William [illegible] (Municipal Technical [illegible], Birmingham.)

It is impossible to discuss the whole art of soldering in a little pamphlet of 22 pages, but the author has put together some very useful notes on the chemistry of fluxes, the composition of hard and soft solders, and gives a few practical hints about their use. The dodges peculiar to electrical work are not mentioned; but even those electricians, and there are many, who can handle a bit or blowpipe in a way that [illegible] an ordinary tinsmith, and can achieve feats of soldering which no workman would have believed possible a few years ago, will find something worth knowing in Mr. [illegible] little book.

THE WORK OF HERTZ.

CORRECTIONS AND EXPLANATIONS BY DR. OLIVER LODGE.

In connection with the illustrations to a lecture of mine at the Royal Institution, recently reported in *The Electrician*, June 8th, 15th, 22nd, there are some misapprehensions which it may be well to set right for the benefit of students and others who may wish to repeat some of the experiments. Many of the experiments lend themselves to easy repetition, since they involve nothing novel in the way of apparatus except what is quite easily constructed; many of them can be performed with the ordinary stock apparatus of an amateur's laboratory.

Figs. 2, 3 and 4 (page 154) are curves obtained by Bjerknes with the apparatus depicted in Fig. 14, which is intended to show

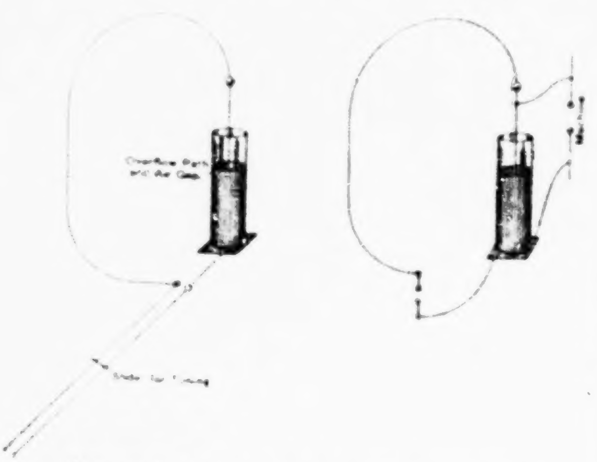
(1) A Hertz vibrator connected to an induction coil;

(2) A nearly closed circuit receiver properly tuned with the vibrator; and

(3) A one-sided electrometer for inserting in the air-gap of 2.

The receiver is not provided with knobs, as depicted in Fig. 14, but its open circuit is terminated by the quadrants of the electrometer, which is shown on an enlarged scale alongside. The needle is at zero potential and is attracted by both quadrants. By calculation from the indication of this electrometer Bjerknes plotted the curves Figs. 2, 3, and 4. Fig. 2 represents the oscillations of the primary vibrator, rapidly damped by radiation of energy. Fig. 3 represents the vibrations thereby set up in the resonating circuit when the two are accurately in tune, and which persist for many swings. Fig. 4 shows the vibrations excited in the same circuit when slightly out of tune with the exciter. A receiver of this kind makes many swings before it is seriously damped.

In Fig. 5 the emitting circuit is properly shown, but the receiving circuit is not shown properly. The following sketch is correct.



Corrected sketch of the Syntonic Leyden Jar experiment.

Fig. 6, if its plates and rods are magnified enormously without magnifying the knobs, may serve to represent the gigantic vibrator mentioned on pages 186 and 187; whereas the ordinary size Hertz vibrator is shown in Fig. 10, on a scale of about an inch to a foot.

A new figure, Fig. 22, may be added instead of the last [illegible] note on page 155, to illustrate the arrangement by which I showed the effect on one spark of the light from another. It will be observed that with this arrangement the B knobs are at the same potential up to the instant of the flash, and in that case the ultra-violet portion of the light of the A spark assists the occurrence of the B spark. But it is interesting to note, what Elster and Geitel have found, that if the B knobs were subjected to steady strain instead of to impulsive rush, e.g., if they were connected to the inner coats of the jars instead of the outer coatings, that then the effect of ultra-violet light on either spark gap would exert a deterrent influence, so that the spark would occur [illegible] at the [illegible] [illegible] illuminated gap. With the original connections it is of course not feasible to illuminate the spark by the light of the other; the sparks are then alternative, not successive.

The work of Elster and Geitel ought to have been mentioned in the penultimate paragraph of p. [illegible], but the omission is repaired in a separate article which is shortly to appear in *The Electrician*.

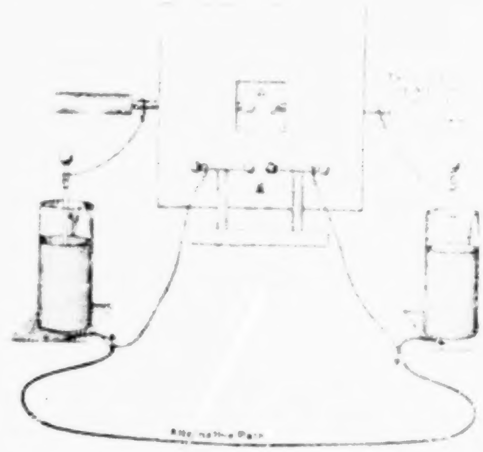


Fig. 22.—Experiment arranged to show effect of one spark of light on another. The B spark occurs more easily when it can see the A spark through the window, unless the window is closed with glass. A quartz pane transmits the effect.

With reference to the silent discharging power of light for negative electricity from clean metallic surfaces, Fig. 6 is drawn much as the experiment was shown, it being understood that the lenses are of quartz, not glass. But there is no need to condense the beam at all in this experiment; the naked arc acts powerfully on clean zinc or aluminium, or, indeed, on most metals. But if there be a few minutes' delay after sandpapering the surfaces the effect is very noticeably diminished. In Fig. 8 all the optical parts are of quartz, and the position of the zinc sphere indicates its position in the most effective region of ultra violet light.

A few lines below Fig. 9 the references in the text have got mixed: the reference to Fig. 9 should be to Fig. 10, and the reference to Fig. 10 should be deleted. The knobs of Fig. 11 should be nearly in contact. Fig. 12 is not a resonator or receiver, but an emitter; it emits a long series of 3in. waves at each spark, and it was arranged against the *outside* of a tinfoil lined box containing battery and induction coil for exciting it. Alongside of it and outside the same box was arranged the larger radiator, Fig. 20, the wires from which pass into the box through glass tubes, and are there connected with the terminals of the secondary coil. The object of this metal lined box or packing-case is to keep in all the stray waves, which else are liable to start from any part of the circuit; i.e., to insure that the ostensible source shall likewise be the real one. The sending arrangement shown in Fig. 21 would do very well, but the box should be of metal. The wires of the receiving circuit are screened from direct radiation by being inclosed in a compo pipe.

Fig. 18 does not represent what I have called a coherer, but a simple tube of iron borings or filings, as used by me following M. Branly. Fig. 17 is the coherer, though the spiral should be longer to give elasticity enough, and no "stop" is desirable as the pressure has to be regulated by trial. The contact best adapted for sensitiveness is one with quite appreciable pressure. Some practice is needed to work with these things.

The spherical radiator shown in Fig. 19, which was at pleasure either two inches or five inches in diameter, though it could excite the filings tube Fig. 18 when 60 yards away in the open air, yet could not excite it perceptibly when screened off by so many walls and metal surfaces as exist between the Library and Theatre of the Royal Institution. It could, however, still easily excite the coherer, which is immensely more sensitive, and also more troublesome and occasionally capricious than is a tube of iron filings.

In Fig. 16 the handle should be shown of ebonite too, to permit a delicate adjustment without discharge. The instrument is intended to be placed on, or otherwise connected with, the cap of an electroscope, while the left hand terminal is connected to its sole or outer case. Any electrification then given to the right hand screw soon causes overflow at the excessively minute spark-gap inside. The leaves only diverge a little way and then suddenly collapse.

FIG. 23.—Zoneplate of Tinfoil on Glass.

A zone plate or series of rings of equal area, made of tinfoil pasted upon glass with alternate spaces bare, is shown in Fig. 23 herewith, and is intended to act as a diffraction lens, concentrating to a focus the 3in. waves from the radiator Fig. 12.

Lastly, a table of numbers interpolated in the second column of page 204, beginning "with reference to the reflecting power . . ." and ending "up against stops," is seriously out of its place, since it interrupts the sense of another paragraph. It belongs properly just above the first italic heading on page 205.

The account of the "optical experiments" given towards the end of the lecture is very compressed. It may be well to give a few additional remarks on this subject in another article.

ARC LIGHTING AT HASTINGS.

F. C. 6

On Saturday last the occasion of the first lighting up by arc lamps of the entire length of the Hastings and St. Leonards sea front and promenade, extending from the extreme easterly end, known as the Fish Market, to the west end of the Marina, was appropriately celebrated. After a banquet, given by the Hastings and St. Leonards Electric Light Company, at which the Mayors of Hastings and Winchester and a number of other gentlemen were entertained, the invited company proceeded to the end of Hastings Pier, where the Mayor of Hastings formally switched on the long line of arc lights. The company then made a closer inspection of the lighting by driving along the sea-front.

For many years a certain amount of arc lighting has been done at Hastings by Brush continuous-current lamps, supplied in series from Brush dynamos, and the ordinary house lighting has been worked on the alternating-current transformer system. This practice entailed the use of two distinct sets of plant at the generating station, and rendered it impossible to combine the two loads, at least as far as the engines and dynamos were concerned. Upon the extension of the public lighting from the original 15 lamps, occupying little more than half a mile of sea front, to the present 52 lamps, extending some two and a half miles, it was very wisely determined to so arrange matters that the steady arc light load might be put on the same generators as would be used for the house supply, thereby materially improving the load factor and economy of the station. The work of carrying out these alterations and extensions was undertaken by the Brush Electrical Engineering Company, who have succeeded in turning out the work in an effective and thoroughly satisfactory manner. Contrary to the teachings of those who maintain that the continuous current arc in invariably gives the best results in street lighting, the conditions on the sea front seem to be such as are favoured by the use of the alternate current arc. The light, which is thrown upwards, strikes pleasantly against the upper portions of the houses which skirt the sea-front, and in this way an effect more generally resembling the even distribution of day light is produced.

Each lamp is fed from a separate transformer, this latter taking the primary power at 2,000 volts and transforming it down to 50 volts. A small choking coil placed in the lamp circuit serves to regulate the voltage on the arc. The transformers of the 52 lamps are grouped in parallel on two pairs of mains, the connections being so made that the failure of either main will extinguish only alternate lamps. These two mains are switched on to the station bus bars, being fed at 2,000 volts from the Mordey-Victoria alternators, which also supply the house mains. The alternators are rope-driven by Raworth steam engines. The contracting company have been ably assisted in carrying out this work by Mr. M. G. Ross, the engineer and manager to the local company, and by Mr. E. Geipel, the resident outside engineer, and all parties connected with the enterprise are to be congratulated on this successful piece of work.

HEINRICH HERTZ.*

The first day of this year took away from us a fellow worker whose loss affects us most deeply. If, after a long career of discovery and a life rich in achievements, one of the old masters of science passes to his rest, we lament his death but we bow to the inexorable laws of nature. In Heinrich Hertz a discoverer of the first rank has been torn away from us in the middle of his work, and almost at the commencement of the prime of life. The sad news has spread far and wide, and so it is very fitting that we also should pay a tribute to his memory. Let us first glance over the development of the external events of his life during the short space of time allotted to it.†

Heinrich Rudolf Hertz was born at Hamburg on February 22, 1857, and was the eldest son of the then attorney (and later Senator) Hertz. His mother was a native of Frankfort-on-Main. After having attended a city school until his confirmation, he studied privately at home during the years 1873-4, and at Easter, 1874, he entered the highest class of the upper school of the Johanneum in his native town. At Easter, 1875, he left school, in his eighteenth year, with a certificate of fitness for the University.

Even as a boy he displayed great talent, but more especially a strong liking for, and an uncommonly great interest in, the exact sciences. As a scholar of twelve years of age he attended Sunday classes in geometrical drawing held at the Technical School. In addition to his scholastic studies he industriously practised the use of tools, and he went through that course of practical training in carpentry and lathe work which is of so great importance to the physicist; his skill enabled him to construct quite serviceable instruments from the simplest materials, and, among other things, he once made for himself a spectroscope.

* Memorial Address by Prof. Hermann Ebert, delivered at the meeting of the Physical Society of Erlangen, March 7, 1894. Translated by James L. Howard.

† For the following biographical notice the author acknowledges his deep indebtedness to Frau Prof. Hertz.

When he left the Gymnasium it became necessary for him to choose a profession. His desire to construct something useful and permanent and his innate modest temperament, which at that time caused him to doubt greatly his ability to accomplish anything satisfactory in pure science, as well as his newly awakened joy at the prospect of making a practical trial of his powers, all these led him to choose the profession of an engineer, and, indeed, that of a civil engineer. As a preparation for this calling he served during the year 1875 as an apprentice in the city engineer's office at Frankfort-on-Main, such preparation being at that time a necessary preliminary before entering the profession. After this he went during the Summer Semester of 1876 to the Technical High School at Dresden. During the twelve months subsequent to October 1876, his studies were interrupted by his year of military service, which he passed at Berlin in the Railway Regiment. In the autumn of 1877 he went to Munich. This was the most remarkable turning point in Hertz's career, which converted him from a man of practice to one of learning. Here he recognised that his nature could only find full satisfaction in dealing with science, and he applied himself in Munich specially to mathematics and physics.

After only a year, in the autumn of 1878, he removed to the University of Berlin, where he entered the laboratory of Von Helmholtz. His progress was unusually rapid. In 1879 he gained a prize offered by the Philosophical Faculty for a research on extra currents induced in coils and wires, a work which presented difficulties both of theory and experiment. In 1880 he graduated as doctor, and in the same year Von Helmholtz chose him as assistant in the Physical Institute, only three years after he had first devoted himself to the study of physics.

At Easter, 1883, when in his twenty-sixth year, he became Privat Docent at Kiel, acting on the advice of Von Helmholtz, and he immediately obtained a commission to teach theoretical physics from the Prussian Minister of Instruction. At Easter, 1885, when twenty-eight years of age, he received a call as ordinary Professor of Physics at the Technical High School at Karlsruhe. From this place originated his epoch-making experimental researches. In 1886 he married Elisabeth Doll, daughter of the Professor of Geodesy at the same High School.

When in the year 1889 death took away from Bonn Clausius, the founder of the mechanical theory of heat, there was no hesitation in conferring upon Hertz, although only thirty-two years of age, the honour of succeeding Clausius; and at Easter, 1889, he was called to Bonn.

Having thus succeeded to a secure and honourable position, respected and admired both in Germany and abroad, at an age when the power of research usually first begins to make itself manifest, he was soon visited by the insidious enemy which was destined to bring so brilliant a career to such a tragic close. In the middle of the year 1892 a chronic blood poisoning, originating, probably, from a gathering in the jaw cavity, had already begun to undermine his hitherto excellent health. The crisis, which occurred in November, 1892, was passed by a successful operation, and he was able to continue his lectures throughout the Summer Semester of 1893, and (although with great effort) until December 7th of the same year, only a short time before his decease. His malady then returned, and in a few weeks proved fatal; he died on New Year's Day in the 37th year of his age. According to the testimony of those who were near him, and particularly of his wife, who nursed him faithfully to the last, his sufferings were indescribable. In him there passed away not only a man of great learning, but also a noble man, who had the singular good fortune to find many admirers, but none to hate or envy him; those who came into personal contact with him were struck by his modesty and charmed by his amiability. He was a true friend to his friends, a respected teacher to his students, who had begun to gather round him in somewhat large numbers, some of them coming from great distances; and to his family he was a loving husband and father.

The course of events in the external life of Heinrich Hertz was simple and plain. But what a world is opened before us when we consider his scientific life, which was bound up within such narrow limits of time! To give a condensed sketch of its development is the object of the present address.

We generally speak only of his later epoch-making researches; they alone have become known far and wide. But it is very instructive to glance once more over the earlier researches from the higher standpoint reached by the later ones. Further, we perceive how the later discoveries which have transformed the whole subject were originated and developed from the former, these being in a certain restricted sense stepping stones to the latter series of experiments, for Hertz was not led by mere accident to his investigations on the propagation of electric waves; it was a comprehensive and well arranged process of argument which was crowned by these researches, even if a happy chance often furnished him with the means of more quickly reaching the goal. I shall confine myself to the electrical researches, and therefore merely mention Hertz's work on the evaporation of liquids and in particular of mercury in vacuo, on the pressure of saturated mercury vapour, his meteorological investigations, his researches connected with elasticity and the theory of solids; these all show the [illegible] work.

His scientific activity began, as we have already seen, with the solution of a prize problem. The research proposed by the [illegible] of the University of Friedrich Wilhelm at Berlin for the [illegible] of 1879 was the experimental investigation of the [illegible] of induced electric currents. The problem, the solution of which was intended to be advanced by this research, was of [illegible] the older theories of electric phenomena a very [illegible]. These theories were based on the assumption that [illegible] fluid which moved through the conductor [illegible] thing of the nature of matter was concerned in electric [illegible] this hypothetical something must possess [illegible] even [illegible] small degree. If it had mass it must possess inertia when subjected to "electromotive forces," and must therefore, when once set in motion, contain a certain amount of kinetic energy by virtue of its mass and velocity. This kinetic energy would manifest itself if the current in a coil were alternately suddenly made and interrupted, because "extra currents" are then set up in the [illegible] consequence of the mutual inductive action of the separate parts on each other, and the energy of these extra currents would represent that of the moving electrical masses. An exact [illegible] estimate of this energy, and hence of the quantity of electricity, say, in a cubic millimetre of a wire traversed by a current, was hardly to be expected because of the difficult nature of the measurements; one had to be content with seeking an upper limit for the quantity of energy and thus furnishing an answer to the question: How great can this quantity of energy possibly be?

The first considerable experimental investigation of Hertz was devoted to this problem. It appeared with the title "Experiments to determine an Upper Limit for the Kinetic Energy of an Electric Current." The result of the experiments was negative; since the upper limit became smaller and smaller the more exactly the experiments were performed, it was necessary to conclude that the quantity looked for would also eventually become zero if all errors of experiment could be successfully eliminated. But it was certainly a matter of great importance for Hertz that in his first research in the domain of electricity he already convinced himself that assumptions as to the material nature of electricity were untenable, and that the postulated fluid vanished just as he sought to detect it with more accurate means of observation.

In this first work, published when he was only twenty-two years of age, great experimental skill was displayed. We find him working with long stretched wires and large wire rectangles which he stretches in the cellar of the laboratory, pieces of apparatus which he was destined to use later in such a masterly fashion as [illegible]. One particularly clever device was the arrangement of a [illegible] tator by the simple rotation of which a complicated system of conductors could be automatically and quickly inserted in the circuit, cut out or reversed, in regular order. That Hertz was even [illegible] master of the mathematical theory, the most important [illegible] his work, is shown by his calculation of the action of the [illegible] turns and layers on each other, that is to say, by his calculation of the self induction of [illegible].

Hertz returned to [illegible] again at the end of [illegible] "Upper Limit for the [illegible] Energy of Electricity in Motion," when he employed a [illegible] which was not only more direct and more sensitive, but at the same time more perfect in its theory. A very thin silver film deposited chemically on glass was traversed by a strong current in one direction; the current density, or, according to the older theory, the amount of moving electricity in a cubic millimetre of silver, was in this case as great as possible. If this moving electricity was only subjected to the electromotive force of the voltaic cell driving it, the plate was traversed symmetrically from anode to cathode; and if two wires leading to a sensitive galvanometer touched the plate at points on a line perpendicular to that joining the electrodes, no current would pass between these wires. The plate was now fixed on a whirling table and rapidly rotated about an axis through its centre perpendicular to its plane. If moving electricity possessed any property analogous to inertia the current would be deflected by this rotation out of its original path, just as currents of air moving over the surface of the earth from the equator to the poles are deflected by its rotation from their south to north direction and strike the [illegible] at a distant angle. In this case a component of the current would pass between the two transverse electrodes, and this would be indicated by the galvanometer, even though only small in amount. Numerous sources of error, thermal currents caused by unequal heating of the two electrodes by the air currents, alterations in the rotating plate due to centrifugal force, &c., all these were encountered and to some extent masked the effect looked for. But Hertz knew how to reduce these sources of error to a minimum by a judicious combination of separate experiments under varying conditions. In spite of this, [illegible] separate observations failed to give any positive result; the upper limit so determined is that the kinetic energy of an electric current whose density (measured electromagnetically) is

unity is, per cubic millimetre of a silver film, not so great as that of $\frac{1}{1000}$th of a milligram moving at the rate of a millimetre per second. At the end of this Paper he points to the possibility of obtaining positive results in the case of electrolytes, in which the motion of the electricity is bound up with that of the material ions. This conjecture of Hertz has been confirmed by later researches of Colley and Descoudres. Here, however, it is not the inertia of electricity itself, but that of the bodies carrying it, by which the phenomena are brought about.

His thesis for the degree of Doctor in 1880 treats of induction in rotating spherical conductors or hollow spheres between magnets according to the theory of Neumann.

(To be continued.)

DIRECT-READING APPARATUS FOR THE DETERMINATION OF THE MAGNETIC QUALITIES OF IRON.*

BY DR. A. KOEPSEL.

The author, who is the designer of the apparatus described, having set out with the idea that for a direct reading instrument an incomplete magnetic circuit must necessarily be employed, began by the investigation of two points: first, whether results could be obtained with an incomplete magnetic circuit which could

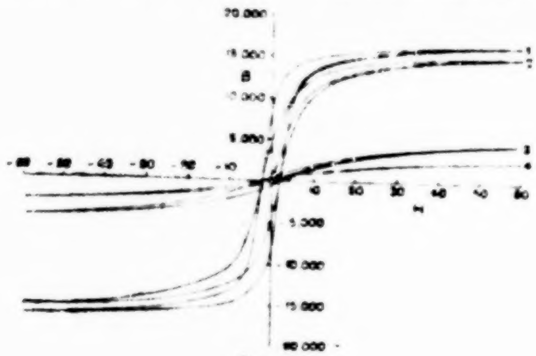


Fig. 1.

be definitely referred to those obtainable with a closed circuit, so that the latter could be easily deduced from the former; and, secondly, whereabouts in an incomplete circuit is the best position for the division, with the object in view of getting the magnetisation curves as correctly as possible. A division in the sample itself was found to be out of the question, as even when the pieces were pressed tightly together a considerable alteration of the curve of magnetisation was observed. Fig. 1 shows in curves 1-4 the

Fig. 2.

curves of magnetisation obtained by the ballistic method from a bar of soft iron 6mm. in diameter, the return being by a large yoke, the curves referring to the following cases:—(1) The bar whole and undivided; (2) The bar cut in two, and the surfaces pressed tightly together; (3) The surfaces 1·3mm. apart; (4) The surfaces 2·5mm. apart.

On the other hand, a division in the yoke itself had comparatively little effect, as shown in Fig. 2, curves 1-3, which represent the curves of magnetisation of a similar bar under the following conditions:—(1) With an undivided yoke; (2) Yoke divided, and the surfaces pressed tightly together; (3) The surfaces 1mm. apart. As the yoke had 100 times the surface of the sample, the magnetic resistance of the division was 100 times as small as in the first case. It is then of great importance to get the yoke as large as possible, which was done in the author's case by making the yoke a solid of rotation, which one can imagine formed by rotating the yoke

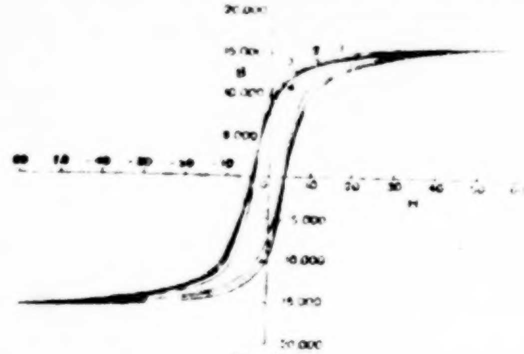


Fig. 3.

about the test bar as an axis, the bar and the magnetising coil being thus completely enclosed. It was then found that, although the curve obtained by pressing the half cylinders together (No. 2, Fig. 3) was not the same as that obtained with an undivided yoke (No. 1), yet the latter could be obtained from the former by the shearing process; and, further, the experiments showed that a gap of 1·5mm. between the cylinders did not very much alter the form and position of the curves (Nos. 3 and 4).

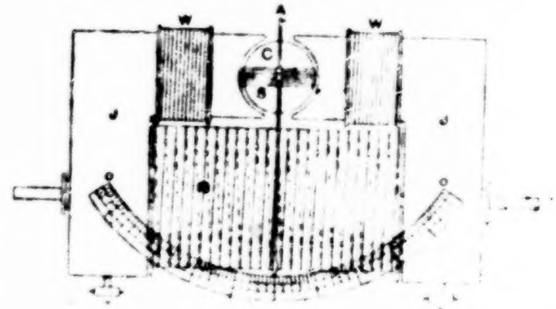


Fig. 4.

A gap of 5mm., however, was enough to afford room for a flat wound coil carrying a current and controlled by a torsion head, the amount of whose rotation to bring the coil to zero is a measure of the field. This coil, however, had to be made very small, and had, consequently, a very small torque; and therefore a design had to be evolved which, while not increasing the air space, should allow of a larger area of coil. This object was attained by return-

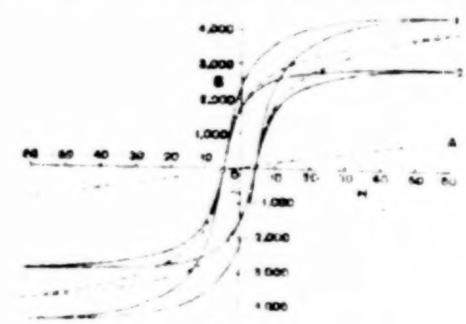


Fig. 5.

ing to the simple form of yoke shown in Fig. 4. The yoke J is bored out at A like the pole pieces of a dynamo, and the piece bored out is replaced by a soft iron cylinder, C, having a diameter 2mm. less, and in the cylindrical air space so made a coil is placed, working on pivots, and capable of rotation, and which is traversed by a current of about 0·01 ampere led in by palladium springs. The openings oo of the yoke serve for the introduction of the

* Elektrotechnische Zeitschrift.

The explanation of the results obtained appears to be that when the cables are charged with positive electricity the polarisation produced is sufficient during the time of one alternation to considerably increase the resistance of the slight leakage to earth by the formation, probably, of a film of oxides; this obstruction is cleared off by the succeeding wave of negative charge, which, as is well understood, opens the leak. The time of an alternation is however, quite insufficient to produce any such effect on the water-pipe earth, and, in consequence, the net result is a passage of negative electricity to earth through the cables, and of the corresponding positive quantity to earth by the water-pipes.

The maximum effect that has been observed so far amounts to an apparent E.M.F. slightly exceeding 10 volts, with the eleven circuits connected to one machine; but it appears that a greater effect would be produced by still further increasing the length of mains in connection.

HEINRICH HERTZ.*

(*Continued from page 274.*)

In 1881 we already find him investigating electrical equations which do not belong to the older theories. An interesting Paper written at this time is "On the Distribution of Electricity on the Surface of Bodies in Motion." The theory of action at a distance shows that in every electrically-charged body at rest the charge resides wholly on the surface, so that the interior of a hollow sphere is quite free from any trace of the hypothetical fluid, and throughout the whole conductor the electric potential has everywhere the same value, even in the interior of the mass of the conductor. Hertz asks himself, "What happens if bodies so charged are moved towards each other?" The distribution of electricity on the surface must at any instant be quite different from that on the surface of bodies at rest, even if these could be brought to exactly the same position in space as the moving conductor momentarily occupies; further, the potential is now no longer constant, either on the surface or in the interior of the body, and whereas a hollow metallic conductor at rest completely screens its interior from external electrical forces, this is no longer the case when the conductor is in motion. Currents are set up in its interior, and along with them heat is developed, resulting in an apparent loss of energy. Continuous motion of charged bodies can therefore only be kept up by supplying external work.

Hertz developed very skilfully the formulæ for these cases, and the general formulæ of electrostatics are greatly extended by them. He applied the general solutions to the specially important case of a solid of revolution rotating in an electric field with constant velocity about an axis, and particularly considered solid and hollow spheres and cylinders. In the latter, even in a uniform field, electric currents are set up which are deflected in a singular fashion by the rotatory motion; inductive effects act through the metallic body upon its interior, so that it no longer behaves as a perfect screen, and so on. In connection with this Hertz arranged an experiment. Over a horizontal and only moderately good-conducting glass plate a needle, provided at its ends with horizontal metallic plates, is suspended by a metal wire. As soon as these plates are charged so that they become electric poles their oscillation becomes greatly damped. The phenomenon is analogous to the damping of a swinging magnetic needle which excites opposing induction currrents in a copper conductor surrounding it. In this work we find the following significant passage:—"If an electric pole be moved at a constant distance above a flat plate the electrification, when once excited, follows it, and the simplest and, indeed, the usual explanation is that the electricity, supposed material, is the thing which moves, but we reject this hypothesis." We here see Hertz already freeing himself from the "usual explanations."

In the year 1883 he devoted his attention to a group of phenomena which always interested him, namely, electrical discharges in gases. In his first work on this subject, "On a Phenomenon accompanying Electric Discharge," he describes some singular luminous rays and cloud-like or arborescent appearances observed when the electrical discharge from an induction coil is allowed to jet out of a tube into a mass of gas which is not too highly rarefied; the positive electrode was inside the tube and the negative one near its mouth. The experiments were greatly varied, and the description of them, although only eight pages long, is full of detail.

To the same year belong the "Researches on the Glow-Discharge," which were carried out in Berlin, although the Paper is dated from Kiel. At that time there existed but three methods for the production and study of the phenomena of electric discharges as they occur in rarefied gases; namely, the influence machine, the induction coil and large voltaic cells of high electromotive force. Of these Hertz chose the third, and constructed a secondary battery with 1,000 pairs of lead plates, enabling him to obtain an electromotive force equal to that of 1,500 Daniell cells in series. The current yielded by it was led by electrodes into discharge vessels of various shapes. Hertz observed more especially the luminous appearances near the cathode with high vacua.

Here it is the rays of the glow discharge and the cathode rays, which are certainly related to them, concerning which Hertz's work discloses many important facts, although he was not able to entirely lift the veil from them. Apparently this was not possible except from his higher point of view attained through the later researches, namely, that of the doctrine of electric oscillations and waves. Even here we find occasional mention of electrical waves and of electrical movements which are propagated through a medium like waves; but the ideas are not yet so clear as they came to be eventually by reason of the later striking experiments.

The first part of the Paper is devoted to an old and much debated question, "Are the discharges through a rarefied gas continuous or discontinuous? Are they still discontinuous in the particular case considered here, when we apply to the gas an apparently continuous battery current?"

Hertz endeavours by ingenious arrangements to prove that his discharges are continuous. On looking over the lines of the argument, however, it is seen that they are only able to establish a lower limit to the number of separate discharges in a second. Whether discontinuities of very high frequency occur or not cannot be definitely decided by the method used, a fact of which Hertz himself was quite aware. If we consider the phenomena after assuming the existence of oscillations, evidence for which is furnished by the striation of the luminous column, thus rendering it analogous to the interference phenomena of a periodically varying source, a distance of 1·5cm. between the striæ, which is easily obtained, would correspond to a wave length of 3 cm. From Hertz's later investigations we know that this represents an electric disturbance, with a frequency of 10,000 million per second. Fluctuations with such high frequencies were no longer observable by the method used, since they do not obey the ordinary laws of electric currents, as was shown by Hertz's later work. I cannot here enter into details concerning the experiments. It would appear that his proof had not satisfied him on this point, for at the end of the Paper referred to he suggests the intermediate assumption, according to which the flow of electricity through a gas is, on the whole, continuous; but that in the tube itself electrical motions of an oscillatory character may be superposed on the constant current, a view which is rendered even more tenable by more recent investigation.

He likewise considered the very important question of the course of the stream lines in a gas traversed by electric discharges. A necessary introduction to this was the proof that cathode rays do not deflect a magnet, although they are deflected by it. It appeared, further, that the cathode rays do not indicate the path of the discharge, but are set up in the course of the discharge, and then obey definite laws of propagation. Experiments upon the absorption of cathode rays were indicated, which have since led to a series of beautiful experiments by Philipp Lenard.

In the last part of this Paper he shows, among other things, that the cathode rays do not exert any electrostatic action, and they certainly cannot be regarded as electrified particles shot out from the cathode, although many physicists often adhere to, and express, this view.

I should like to refer to the experiments here described concerning the peculiar property of cathode rays, that of bringing about the equalisation of electric potential in a direction transverse to them, and so promoting "transverse discharges," experiments which have been extended by other observers. This behaviour of cathode rays reminds us of a quite analogous property of light waves, discovered by Hertz; namely, that the ultra-violet waves possess the same equalising power in a high degree.

The general results of the work can be better understood when it is stated that they support a view expressed in similar form by other observers, for example, E. Wiedemann and Goldstein, namely, that the cathode rays consist of a certain form of ether-motion more nearly allied to light than to any other natural agent, and that they are set up by electrical actions; but afterwards constitute an independent phenomenon, just like the light sent out from an electric lamp.

(*To be continued.*)

* Memorial Address by Prof. Hermann Ebert, delivered at the meeting of the Physical Society of Erlangen, March 7, 1894. Translated by James L. Howard.

Transmission of Pictures by Electric Current.—M. Bertillon, the inventor of the anthropometrical system of identification adopted by the Paris police, is endeavouring to revive the use of the picture telegraph, as he thinks that it would be of the greatest service in rapidly transmitting and disseminating the portraits of suspected Anarchists and other criminals.

fully into the question, and arrives at the conclusion that the image measured in this way is 1⅓ times the true diameter of the pupil, and thus shows that it is necessary to multiply the measurement actually obtained by ¾ in order to get the true result. When this correction is made these pupillometers give a perfectly accurate result. They are simple in construction and rapid in action. The errors arising from parallax and from confusing the border of the iris with the pupil, which are so serious in most pupillometers, are entirely overcome in this.

The simplest form employed in the author's experiments was one due to Robert-Houdin, and is illustrated in Fig 2. It consists of a shallow copper cylinder 12 millimetres deep, the front being provided with an opening and a small hole, *b*. A screen pierced with a small hole, *a*, and provided with an index, *c*, slides over this opening by turning about an axis, *d*, in the circumference of the circle. The distance between the two holes *a* and *b* can be read off on the scale by the index *c*. All lateral light can be shut off by the use of a dark cloth. Other instruments have been devised on the same principle. One due to Gorham consists of a metal tube closed at one end with the exception of a radial opening. A metal disc pierced with holes arranged radially in pairs at various distances apart is attached at the closed end of the tube in such a manner that it can be turned so as to present different sectors to the radial opening at the end of the tube. In this manner, by looking along the tube and turning the disc, two bright spots of light are seen, and the distance apart of the spots seen can be regulated by simply turning the disc. When two of the holes are such that the circles of diffusion touch each other, it is known that the distance

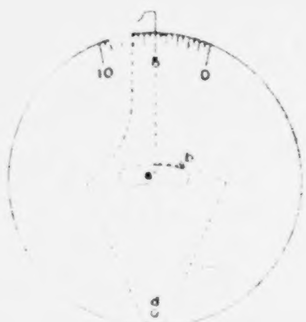


Fig. 2.

apart of these holes is equal to the diameter of the pupil. M. Gorham proposed to use this instrument as a photometer by measuring the size of the pupil when the tube is turned towards different lights. The distances of the lights were adjusted till the diameter of the pupil was the same whichever light was looked at, and it was assumed that under these circumstances the square of the ratio of the distances was equal to the relative candle power of the lights. This assumption is, however, doubtful, as the contraction of the pupil does not depend merely on the intensity of the illumination. Before concluding the account of the various pupillometers yet devised the method of photographic records used in 1887 by Beliarminoff must not be forgotten. This scientist used a chronophotographic apparatus, by means of which the diameter of the pupil could be ascertained at any instant during the course of the tests. This method undoubtedly is the most accurate, but it is too complicated and costly for use.

As regards the direct action of light upon the iris, some experiments made by Brown Séquard in 1847 appear to prove that only the luminous rays have any effect, heat rays and chemical rays being inactive. The eyes experimented upon were those of fish and bratracians. They were extracted from the orbits immediately after death, and the pupils were found to contract on the approach of a candle, and to expand again in the dark, the effects being reproducible some times as frequently as 100 times in an hour. The interposition of a plate of alum did not alter these effects, showing they were not the result of heat rays. The persistence of the pupil movements, long after the nerves had lost all sensitiveness to irritation, seemed to prove that the action was muscular and not nervous. Moreover, utilising the fact discovered by Brücke that the cornea and crystalline of the ox and the rabbit absorb the violet and ultra-violet rays, light was allowed to fall on the eyes of frogs after having been previously filtered by passing through the eye of a rabbit. The pupillary contraction was found to take place just as before. All the evidence is thus in favour of the view that only the luminous rays are capable of producing the movements of the iris. Experiments of a like nature on human eyes are however, still wanting, and it is to be hoped that some will before long be made.

Actual measurements of the diameter of the pupil of the eye have been very rarely made. Lambert, in his book on photometry published during the last century, gives a few measurements and conclusions founded on them. The principal of these conclusions is that if the eye be exposed to different degrees of illumination, the area of the pupil exposed does not vary inversely as the illumination, but in such a manner that the product of the illumination and the area exposed becomes less and less the feebler the illumination. M. Charles Henry is trying to reproduce these experimental results of Lambert with better and more reliable apparatus.

HEINRICH HERTZ.*

(*Continued from page 299.*)

The last research carried out in Berlin is entitled "On the Behaviour of Benzine as an Insulator and Absorber." All insulating materials exhibit in a greater or less degree the often very troublesome property of absorbing and retaining a portion of the electric potential acting upon them. In the older theories this process of "absorption" is represented by assuming that the electricity partially wanders from the charged condenser plates into the insulating material between them, and is there retained. But it was soon observed that the property of absorption is essentially connected with want of homogeneity of material, so that homogeneous crystals, for example, exhibit the phenomenon only in a small degree. In order to obtain more definite results Hertz undertook experiments with liquids which can easily be rendered perfectly homogeneous, and he found in commercial benzine a medium which insulated sufficiently well for his purpose. It then appeared that the dielectric power of benzine increased under the continued action of electric forces. The cause of this was traced to the increase in the amount of suspended or dissolved impurities which were set free; under the influence of electric charges, therefore, the liquid is "electrically cleaned." It was evident, also, that the power of absorption decreased after this prolonged cleaning, so that this property must really be attributed to want of homogeneity. No migration of free electricity takes place, but the electric stress takes hold of the separate foreign particles embedded in the medium, and arranges them in a sort of strained or polarised condition. Hertz showed that this was the case by suddenly letting the liquid flow out of the trough which he had used as a condenser in these experiments, or by lowering into it two metallic plates connected with an electrometer, which clearly indicated the presence of this polarised state in the medium.

Although somewhat anticipating its chronological order I will here mention a short communication "On the Dimensions of a Magnetic Pole in Different Systems of Units," in which Hertz took part, although quite objectively, in the then burning question of the dimensions which should be chosen for electric units. He shows that the so-called "electro-magnetic system" is not more justifiable than the "electrostatic system," simply because it does not lead to want of agreement between the theories of Maxwell and Clausius; he then points out the cause of this want of agreement, and shows that the ratio of units in the two theories is exactly inverted if the magnetic measure of the current is taken as a starting point instead of the electric one.

We come now to the unique and splendid theoretical investigation of the year 1884, which is certainly the most important one in connection with the further development of Hertz's ideas, namely "On the Relations between Maxwell's Fundamental Equations of Electrodynamics and those of Opposed Theories." We may characterise this as Hertz's greatest contribution to theoretical physics.

As the title itself indicates Hertz now declares himself definitely opposed to the orthodox theories of electric phenomena which at that time were put forward in Germany, and he passes over to the camp of Maxwell's followers. But why does he take this step? He

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was not attracted by the fact that in Maxwell's theory at that time the part which explained light as an electro-magnetic phenomenon was still shrouded with a certain degree of mystery. He was not allured by the wide perspective and the multitude of new problems towards the solution of which a researching mind would be attracted; no, it was after a prolonged struggle with his inward conviction that he freed himself from the old ideas which had become fast rooted even in him. He proves, firstly, that the systems of equations of the older theories are incomplete, that from them certain members are missing, the absence of which even a supporter of the theory of distance action would concede to be a defect. But if these terms are added the formulæ begin to be unwieldy and awkward; in place of finite expressions we have infinite series which certainly converge towards a finite limit, but which appear so opposed to nature that the dissatisfaction on arriving at such formulæ is not compensated by the fact that we at last possess the complete expressions for the observed phenomena. Hertz then obtains from the unwieldy formulæ a system of equations of great clearness and simplicity, a system which is immediately greeted as a known one in Maxwell's theory. The necessary improvement in the older theories leads, therefore, to that of Maxwell, and this must be chosen as the starting point in all further progress. But even Maxwell's formulæ are here expressed in a clearer form, and this is an important advance in the theory. Maxwell, free as he was, could not completely emancipate himself from the older views, and his formulæ possess a slight unwieldiness and want of simplicity, traceable to the fact that the fundamental idea of his theory is not yet logically and clearly expressed by them; they still contain traces of conceptions belonging to the older systems, rudimentary conceptions, as Hertz occasionally and significantly calls them. Hertz has definitely removed these rudimentary notions, thus clearly exhibiting the kernel of Maxwell's theory. Already in this Paper of 1884 we meet with that system of six partial differential equations which served afterwards as Hertz's guide along the tedious and devious path of his experimental researches.

Hertz had thus acquired new views from his theoretical considerations, and with this discovery in theory his life work was indicated for him. He must now strive to prove experimentally the superiority of Maxwell's theory and to trace all the immediate consequences of it. That the task of finding out the best method was no easy one even for a Hertz we may infer from the fact that he was occupied during three years merely in preparing the necessary apparatus.

One of the most important consequences of Maxwell's theory was that disturbances of electrical equilibrium produced at any place must be propagated as waves through space with finite velocity, indeed, with the velocity of light. This was plainly a fact to work upon. If this propagation was to be traced through the space inside a laboratory the disturbances must be rapid, and if a definite effect was to be observed they must also follow each other at regular intervals; that is, periodically varying electrical conditions, or electric oscillations must be set up, the period of which would have to be very small so that the corresponding wave length, taking into account the extraordinarily high velocity of propagation, should be only a few decimetres.

The method of exciting electrical oscillations was indeed known, and that of producing rapid electric disturbances had already been investigated in Helmholtz's laboratory. As far back as 1870 Von Bezold had actually measured the length of electric waves and observed their interference in wires, and yet some links in the chain were wanting. One, or rather two, further conditions were necessary. We are fortunate in possessing Hertz's own account of the origin of his epoch-making work. In the introductory notice to his collected Papers on electric waves* he gives a classically beautiful picture of the gradual advance of a genius in research, in which his modesty compels him to omit much that we ourselves must fill in, namely, the importance of his earlier work.

He tells us that his interest in electrical oscillations was originally awakened by the Berlin prize of 1879, which was to be awarded for an experimental proof of a relation between electro-dynamic forces and dielectric polarisation in insulators. Prof. von Helmholtz advised young Hertz to devote himself to this research. Hertz discovered, however, that the then known oscillations were too slow to ensure success, and he therefore gave up the research; but from that time he was on the look out for everything connected with electrical oscillations. Consequently he immediately recognised the importance for his purpose of an observation which in itself appeared very trivial. One of those accidents occurred which often point the inquiring observer to the right path and lead to important consequences. Hertz tells the story himself very neatly. In the collection of physical apparatus at Karlsruhe he found an old pair of so-called Riess's or Knochenhauer's spirals; short, flat coils of insulated wire, with the turns all in the same plane. Hertz showed them in lecture and performed experiments with them. He there

* "Electric Waves," by H. Hertz, translated by D. E. Jones. Page 1. (Macmillan.)

upon noticed that the discharge of a [illegible] small induction coil passed through [illegible] induced currents in the other, [illegible] spark gap was inserted in the circuit of the first one. [illegible] the discovery of the "effective spark gap" [illegible] quantitative measurements possible. [illegible] previously been somewhat [illegible] complicated, and above all this [illegible] experiments in which sparks played [illegible] upon as "impure" [illegible] Hertz [illegible] detected [illegible] provided only the discharges [illegible] jars for example [illegible] small capacity [illegible] the paths of the discharge were of simple form and [illegible] consisting of [illegible] wire [illegible] conditions were fulfilled an electrical [illegible] electrical [illegible] of similar shape and [illegible] We have here the real kernel of Hertz's discoveries, and [illegible] sum up the experimental evidence of all [illegible] following sentences.

1. If we allow small condensers with small [illegible] through short and simply constituted circuits [illegible] long spark gap, we obtain a sharply defined discharge of very short duration, which is the long sought for sudden disturbance of electrical equilibrium. This was a discovery which [illegible] by no theory, a newly discovered property of [illegible] which, however, all the later work depends. [illegible] further that at the same time success was [illegible] point, since oscillations of the required period were [illegible] that Hertz had now a powerful exciter of electrical [illegible]

2. Such [illegible] are capable of exciting in another [illegible] circuit of [illegible] form resonance phenomena of sufficient [illegible] even when the two circuits are separated from each other by [illegible] distances. Hertz had therefore to find a receiver by means of which he could detect the waves produced by the exciter and propagated to any distance.

In the work which next appeared, "On very Rapid Electric Oscillations," we find him [illegible] with these phenomena [illegible] studying his apparatus, and gradually [illegible] it. As an exciter of oscillations he uses wire [illegible] metal rods, to the ends of which metallic cylinders [illegible] connected. The exciter is broken in the middle by [illegible] with small spherical knobs, between which [illegible] exciter is charged by an induction coil [illegible] whose discharge only plays a secondary [illegible] into consideration. The receivers are [illegible] simple [illegible] wire, likewise provided with spark gaps [illegible] that they show the maximum resonance effect [illegible] they are "electrically tuned." When a [illegible] up in them, sparks pass across the gap, and the greatest [illegible] the spark measures the intensity of the effect.

Such is the principle of the new and simple means which Hertz has introduced into the physical laboratory, and with which [illegible] physicists are at present working in various directions [illegible] endeavouring to penetrate into the unknown. It was owing to a strange accidental circumstance that the [illegible] discoveries and the later work of Hertz met with immediate recognition rather than to their intrinsic value; how often the greatest discoveries [illegible] long unheeded! Hertz found in his earlier experiments on electric resonance a phenomenon which attracted his notice by [illegible] ness and singularity, and [illegible] inexplicable character. It was seen that [illegible] of the resonance sparks were [illegible] the primary circuit. If the [illegible] spark gap they appeared small and hardly [illegible] came immediately larger and [illegible] between the two spark gaps. In his [illegible] ultra-violet light on the [illegible] drawn [illegible] came to the conclusion that this [illegible] is traceable only to ultra-violet [illegible] tinued these researches and discovered [illegible] cerning them. Indeed, Hertz [illegible] experimental physics, that of the action of light [illegible] these experiments did not [illegible] closer relation between the two phenomena [illegible] Hertz popular, so that everything [illegible] read.

Few people, however, [illegible] though only subsidiary [illegible] we were on the [illegible] electric oscillations. We find Hertz [illegible] ratus. In the following year appeared [illegible] linear Electric Oscillation [illegible] most difficult and the most important of Hertz's experimental researches; it is often [illegible] it forms a necessary step to the following [illegible] become familiar with the phenomenon of resonance, he has now

to deal with the propagation of oscillations through space. The apparatus was already furnished; as exciter he made use of a straight metal rod with a spark-gap in the middle and a spherical conductor at each end to give it capacity. When sparks pass rapid electrical surgings occur; we have a rectilinear oscillation whose effect is radiated out into surrounding space. As receivers he used tuned circles of wire, likewise provided with very small spark-gaps whose length could be measured with a micrometer. These were brought into all kinds of positions with respect to the exciter, and Hertz studied and measured the effects. These effects were very different at different points in the neighbourhood and in the various positions of the receiver, but a law was soon found to apply to them. "The discovery and disentanglement of these extremely regular phenomena gave me peculiar pleasure," says Hertz. By an argument which was ingenious, though simple in its results and indisputably clear throughout, he established in each case how the electrical radiation must act at the different points in the neighbourhood of the oscillation, in order to produce the observed effect on the receiver, and he finally succeeded in giving a clear and intelligible account of the propagation of the radiation through space. Many remarkable phenomena then presented themselves, of which the older theories could offer no explanation. In the same year, 1888, he showed in his Paper on "The Forces of Electric Oscillations, treated according to Maxwell's Theory," that this theory gives exactly the same distribution of forces as his experiments had yielded, with all their peculiarities and apparent anomalies. Hertz set out in this Paper from the simplified form of Maxwell's theory which he had established in 1884.

Great discoveries now followed one after another, each representing a new triumph of Maxwell's theory, and, above all, of the newer views. The papers which were presented to the Berlin Academy between November 10, 1887, and December 13, 1888, mark a new era.

The Berlin prize problem now received a definite solution in the research "On Induction Phenomena produced by Electric Disturbances in Insulators." It was shown that "alternating conditions of electric stress or dielectric polarisation" produce electro-dynamic action and inductive effects, analogous to those set up in a conductor by a rising or decaying voltaic current. The older theories had for the most part disregarded the intervening medium, according to them the effect travelled directly across it, whereas Maxwell's theory had these electro-dynamic actions as one of its most important consequences. At the same time the old controversy concerning the action of "unclosed circuits" was set at rest.

Three months later appeared the Paper "On the Velocity of Propagation of Electro-dynamic Actions." In this research an experimental proof was given of the fact that electro-dynamic actions are propagated through space with finite velocity. For the velocity of electric waves in air a quantity of the same order as the velocity of light was obtained. For the velocity of propagation along stretched wires he found a value different from that in air; theory required them to be the same. In consequence of an error in calculation the velocity of waves in wires was found smaller than the velocity of light. But he here showed himself an unbiassed lover of truth. Although convinced of the truth of the theory he submitted his actual results, and confessed that he had here met with an unsolvable difficulty. Let us quote his own words on the subject, written four years later in the introduction to his book after he had explained the discrepancy:—"I have described these results in great detail because I wished to convince the reader that I was not merely endeavouring in this research to support a preconceived opinion by the most convenient and suitable interpretation of experiment. On the other hand, I have carried out the experiments, which in themselves were not easy, with the greatest possible care in the face of a preconceived opinion. And yet, with all my good fortune, I have had decided misfortune just in this experiment. For, instead of reaching the true result with small trouble, which a properly arranged plan would probably have enabled me to do, I have apparently taken great pains, and fallen into error."

It was not discovered until later that the deviations from the theory were caused simply by the walls of the room, which reflected the electric waves impinging on them. Edouard Sarasin and De la Rive have finally shown that the velocity of propagation in wires has the same value as in air, each being that of light, by repeating Hertz's experiments on a large scale, and with every precaution, in the large machine shop of the Geneva Waterworks. The result is therefore quite decided for us now; but the disturbances which crept into Hertz's own experiments have given us a proof of his conscientiousness.

The account of the research "On Electro-dynamic Waves and Their Reflection" was published in the same year. Although Hertz had hitherto only succeeded in working with waves propagated along a wire, he now demonstrated the existence of similar waves in free space. Opposite the radiator a large screen of zinc plate, 4m. square, was suspended on the wall; the electric waves emitted from the radiator were reflected from this plate, and [illegible] the direct waves interference phenomena were produced, consisting of stationary waves with nodes and loops. When, therefore, Hertz moved the circle of wire which served as a receiver to and fro between the screen and the radiator the sparks in the receiver circuit disappeared at certain points, reappeared at other points, disappeared again, and so on. Thus there was found a periodically alternating effect corresponding to nodes and loops of electric radiation, showing clearly that in this case also the radiation was of an undulatory character, and the velocity of its propagation finite.

In the Paper "On the Propagation of Electric Waves along Wires" he shows that alternating electrical movements with frequencies as great as those under consideration (about a hundred million per second) are confined to the surface of the conductor along which they are propagated, and do not penetrate into its interior. This is a very important experimental confirmation of a theory of Poynting, founded upon the ideas of Faraday and Maxwell, concerning electric currents. According to this theory an electric current is a phenomenon which has its seat in the region outside the wire conveying it rather than in the interior of the wire. The magnetic effect of a current shows us that something goes on in this outside space which is very closely connected with the passage of the current. We are not to look for something flowing along the wire, but must rather consider that the energy enters the wire from without, and is thereupon converted into the special form of heat. It is thus not the copper core of a cable which conveys the energy from the sending to the receiving station, but the insulating layers surrounding the core; the terms "conductor" and "non-conductor" exactly change places. It is certainly true, as Hertz very pointedly remarks, that this apparent paradox only arises because we neglect to state what we mean by the term *conduction*. In reality the electric fluid of the older theories is abolished, in its stead have been introduced electric and magnetic forces existing independently in space, and advancing through it, carrying their energy with them, and for these the circumstances of conductivity are exactly the inverse of those for the hypothetical electric fluids.

In the course of his experiments Hertz had learned the method of producing, and working with, very short electric waves of 30cm. length. The oscillations corresponding to them could be collected by a concave cylindrical mirror and concentrated into a single beam of electric radiation. According to Maxwell's electro-magnetic theory of the phenomena of light such a beam must behave like a beam of light. That this is the case was shown by Hertz in his Paper "On Electric Radiation," the communication which has become the most popular one, and has created the greatest astonishment far and wide. The modest man says, in the introduction to his collected Papers, "These experiments succeeded each other quickly, and without any difficulty. The experiments with the cylindrical mirrors soon attracted notice, and they have been often repeated and verified. They have met with an approval quite beyond my expectation."

He showed how such electric radiation was propagated in straight lines like light, that it could not pass through metals, but was reflected by them; that, on the other hand, it was able to penetrate through wooden doors and stone walls; he also proved, by setting up metallic screens, that a space existed behind them in which no electric action could be detected, producing in this way electric shadows; and, by passing the rays through a wire grating, he succeeded in polarising them, just as light is polarised by passage through a Nicol prism. But the most striking experiment was that in which he directed the electric ray on a large pitch prism, weighing about 12cwt.; the ray was deviated, being refracted like a ray of light in a glass prism. Thus he gave to the whole its finishing touch, and the edifice was now completed.

In the communication which appeared three years later and thus was dated from Bonn, "On the Mechanical Effects of Electric Waves in Wires," he demonstrated that not only does a wave of changes of electric state travel from the radiator through space with the velocity of light, but that along with it and inseparable from it there exists a magnetic wave, as theory requires.

In his last experimental work he finally returns to the phenomena of discharge in gases, and shows, almost at the same time as [illegible] Wiedemann and Ebert, that cathode rays can pass through thin films of metal, but are stopped by a dielectric film, no matter how thin it may be.

And now inexorable death set a limit to the further progress of the clever experimenter. We are indebted to him for [illegible] other Papers of a theoretical character, "On the Fundamental Equations of Electro-dynamics in Bodies at Rest and in Motion," which mark a great advance in the mathematical theory of electric and magnetic phenomena.

On his deathbed he completed a work, "On the Principles of Mechanics," to the early appearance of which the scientific world looks forward with intense interest.

Let us once more pass in review the chief results of his discoveries. He has freed us from the [illegible]

at a distance, and concerning electrical and magnetic effects he has shown that they are propagated from particle to particle through space with finite velocity. This is a result of great and general, one might almost say philosophical, significance. The mysterious darkness which surrounded those secret distance actions of former times has been cleared away; the dogma, honoured by science until now although unwillingly tolerated by reason, that something can act where it is not, has lost its application to the case of electric and magnetic actions. Further, the identity of the form of energy in the case of two powerful agents in nature has been conclusively established; light and electrical radiation are essentially the same, different manifestations of the same processes. The old elastic-solid theory of optics is thus resolved into an electromagnetic theory. The velocity of propagation of light is the same as that of electro-magnetic waves, and these obey the laws of optics; the scope of optics is enormously widened; to the ultra-violet, visible and infra-red rays with their wave-lengths which can be reckoned only in thousandths of a millimetre, are to be added waves many metres in length; the spectrum is infinitely extended, even if the rods and cones of our eyes do not respond to the new vibrations.

But in another direction we owe much to Hertz's investigations; we are, it appears to me, brought much nearer by them to a solution of the burning question, "What is electricity?" Hertz shows that there is no real electricity which can be regarded as a fluid as in the older theories; what we wished to explain by assuming it are conditions or states of a medium which, although hypothetical, manifests itself by its effects, "the ether," which permeates all matter. Led to this hypothesis, the phenomena of magnetism, electricity, and light apparently find at last a single explanation in a "Mechanics of the Ether." Whenever such an edifice is completed we shall be considerably nearer the possibility of finding a single explanation for the whole of nature. These are the results of the most recent discoveries, in which Hertz has played a most conspicuous part.

If we glance over the list of his contributions to science, we ask in astonishment, "Is it possible that one man in the space of thirteen years could furnish such a wealth of new discoveries or open so many new avenues of research?" If the intense suffering of Hertz and his premature decease awaken our deepest sorrow, if the thought of what this mind might have explained makes us rail against the bitter fate that tore him from us, we may still say his was a short but happy and richly rewarded life; the fame of our Hertz is secure, and will shine out during centuries of increasing intellectual development, whatever great deeds they may hide in their bosom; the influence of his discoveries will make itself felt as long as electromagnetic waves continue to heat and illumine the earth.

AMERICAN NOTES.

(FROM OUR OWN CORRESPONDENT.)

NEW YORK, *July* 7, 1894.

Long Distance Electric Roads.—Every now and then we hear of a new scheme for a long distance electric railway, the latest project being for one between Washington and New York, whose promoters have applied for incorporation. None of these ambitious schemes have thus far gone beyond the promoting stage, unless we except the feeble attempts made by the Chicago-St. Louis line, whose prospectus dwelt in such glowing terms on the profits to be derived from transporting World's Fair visitors. In some cases the scheme for a long distance line conceals another purpose, the real object being to secure franchises on better terms for short lines, which are represented as sections of a trunk line which is never built.

Purifying Water and Deodorizing Garbage.—Some of the members of our Tammany City Government seem to be greatly interested in a process for purifying the municipal water supply and deodorizing city garbage by electrical means. In the former case sea water through which an electric current has been passed is mixed with the regular water supply in homeopathic doses. We cannot learn how the process is to be applied to deodorize a garbage island that has become a pestilent nuisance, but this use has been proposed. As residents in the vicinity have applied for an injunction against further dumping there, though in the face of the promise of wonders when the electrical apparatus gets started, we fear that this latest political contribution to electrical science may not have an opportunity to demonstrate its merits in this respect.

Electro Medical Science.—An employé of the Edison lamp works of Harrison, N.J., a few days ago was rendered unconscious by a shock from an electric current, in which state he remained for several days, notwithstanding the efforts of his physician. Finally, becoming convinced that the patient did not recover on account of being "full of electricity," the doctor, applying his electrical knowledge, connected one end of an insulated wire to a water pipe and the other end to a damp sponge, which was rubbed over the body of the injured man. After the first application an improvement was noticed, we learn, and in a short time the patient recovered consciousness and is now convalescent. All of which is hailed by the newspapers as a new curative principle for the treatment of electric shocks.

CORRESPONDENCE.

ENGINE REPAIRS.

TO THE EDITOR OF THE ELECTRICIAN.

SIR: I am glad to find from Mr. A. Lazenby's letter that the difficulties with closed type engines referred to by me in "Electric Motive Power" are now lessened in the improved types of the Willans engine; and I note that in condensing engines the temperature of the lubricant in the crank chamber does not often exceed 150° F.—Yours, &c.,

Suffolk House, Cannon-street, E.C., July 16, 1894. ALBION T. SNELL.

LIGHTNING AND WOOD CASING.

TO THE EDITOR OF THE ELECTRICIAN.

SIR: With reference to your remarks on page 157 regarding the phenomenon of sparking resulting from Hertzian waves impinging upon separated main leads terminating in two flexible conductors, I should like to point out that danger is also incurred where insulated conductors of opposite poles are placed in contact with each other at the points of crossing in wood casing. In some wiring I have inspected, the first fuse protecting these points was either the main, or was of such large diameter as to render it doubtful if it would act at the comparatively small current that would result from an arc so formed. If the fuse did not blow, and the arc was maintained, the wood casing in the immediate neighbourhood of the latter would probably become ignited.

If this occurred during the night, or at any time with no one at hand to switch off, or if no main switch were provided, it might be difficult to extinguish the fire or limit the damage.

As far as my experience goes, this faulty method of wiring appears to be on the increase, and it would be advisable for fire offices to insist on the separation of conductors until protected by a small fuse.—Yours, &c.,

July 6, 1894. CHAS. A. GAWTHROP.

LARNE.

TO THE EDITOR OF THE ELECTRICIAN.

SIR: Your "Note" with reference to Larne in *The Electrician* of the 13th inst. is inaccurate, as there has been no new penalty clause added to our agreement. At the meeting you refer to, the engrossed copy of the agreement was before the Board for signature; but a Commissioner objected to its being completed on the ground that the penalty clause of the draft copy had been omitted in the fair copy, and it was then decided to consult the Board's solicitor, by whom the agreement had been prepared. The solicitor attended a special meeting on the 7th inst., and was able to show the doubting Commissioner that his suspicions were groundless, and that there was no necessity to make any alterations or additions to the agreement. It was then signed by the Chairman and two Commissioners. The discussion over this lighting agreement has been vigorously carried on since last October, and, apparently, there are some members of the Board who do not think the matter has received adequate attention even now. The arc lights referred to are of 1,200 c.p. each, and not of 1,700 c.p. as printed.—Yours, &c.,

Electric Light Station, Larne. ARCHER TURNER, Manager and Engineer.

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DEFENDANT'S EXHIBIT J-4

adapted to remove any doubt as to the identity of light, radiant heat, and electromagnetic wave-motion. I believe that from now on we shall have greater confidence in making use of the advantages which this identity enables us to derive both in the study of optics and of electricity.

Explanation of the Figures.—In order to facilitate the repetition and extension of these experiments, I append in the accompanying Figs. 35, 36_a, and 36_b, illustrations of the apparatus which I used, although these were constructed simply for the purpose of experimenting at the time and without any regard to durability. Fig. 35 shows in plan and elevation (section) the producing mirror. It will be seen that the framework of it consists of two horizontal frames (a, a) of parabolic form, and four vertical supports (b, b) which are screwed to each of the frames so as to support and connect them. The sheet metal reflector is clamped between the frames and the supports, and fastened to both by numerous screws. The supports project above and below beyond the sheet metal so that they can be used as handles in handling the mirror. Fig. 36_a represents the primary conductor on a somewhat larger scale. The two metal parts slide with friction in two sleeves of strong paper which are held together by indiarubber bands. The sleeves themselves are fastened by four rods of sealing-wax to a board which again is tied by indiarubber bands to a strip of wood forming part of the frame which can be seen in Fig. 35. The two leading

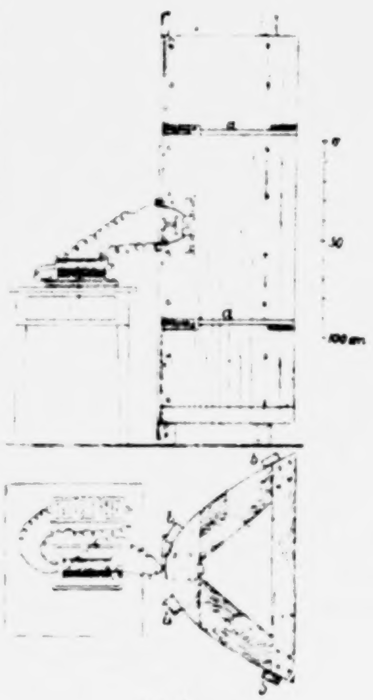

Fig. 35.

wires (covered with gutta-percha) terminate in two holes bored in the knobs of the primary conductor. This arrangement allows of all necessary motion and adjustment of the various parts of the conductor; it can be taken to pieces and put together again in a few minutes, and this is essential in order that the knobs may be frequently repolished. Just at the points where the leading wires pass through the mirror they

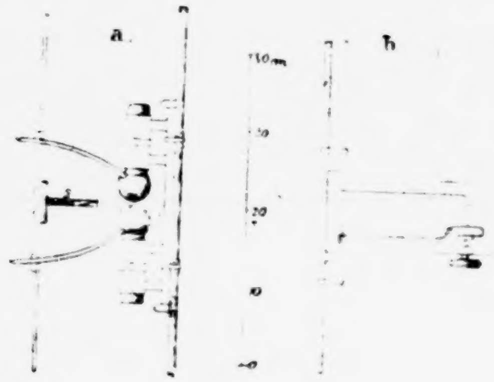

Fig. 36.

are surrounded during the discharge by a bluish light. The smooth wooden screen s is introduced for the purpose of shielding the spark-gap from this light, which otherwise would interfere seriously with the production of the oscillations. Lastly, Fig. 36_b represents the secondary spark-gap. Both parts of the secondary conductor are again attached by sealing-wax rods and indiarubber bands to a slip forming part of the wooden framework. From the inner ends of these parts the leading wires, surrounded by glass tubes, can be seen proceeding through the mirror and bending towards one another. The upper wire carries at its pole a small brass knob. To the lower wire is soldered a piece of watch-spring which carries the second pole, consisting of a fine copper point. The point is intentionally chosen of softer metal than the knob; unless this precaution is taken the point easily penetrates into the knob, and the minute sparks disappear from sight in the small hole thus produced. The figure shows how the point is adjusted by a screw which presses against the spring that is insulated from it by a glass plate. The spring is bent in a particular way in order to secure

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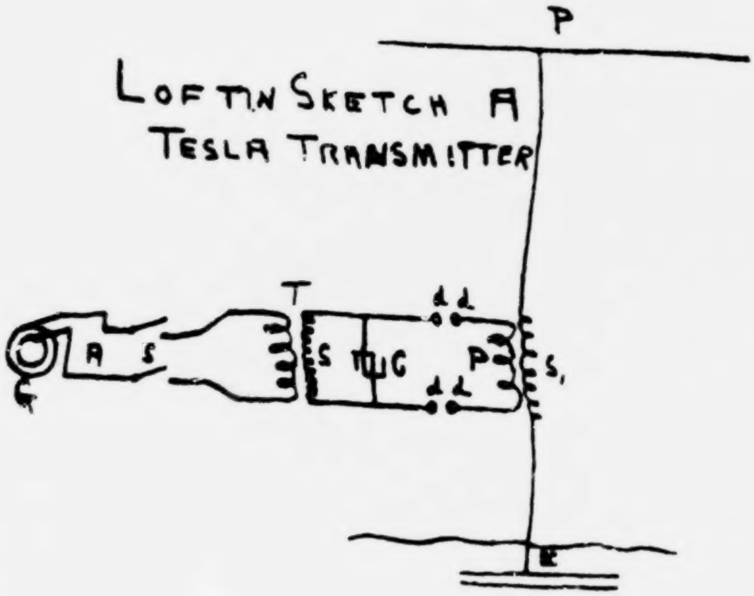

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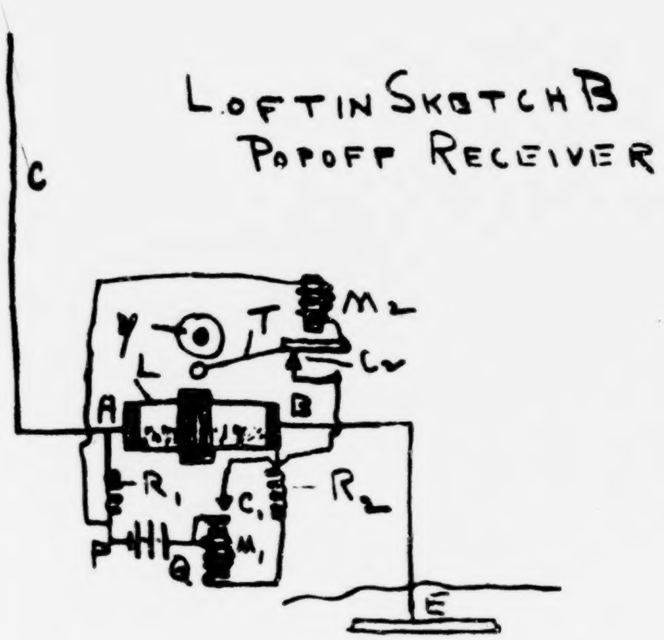


Navy Manual, by Robison, 1915

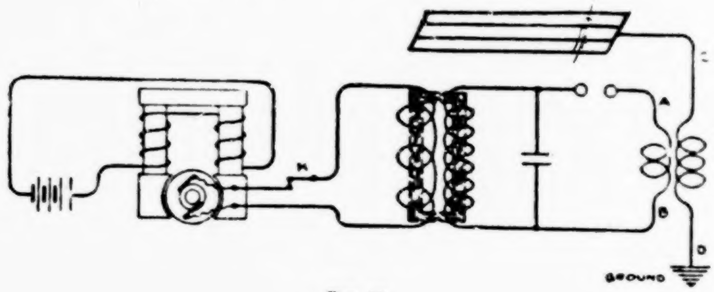


Fig. 29.

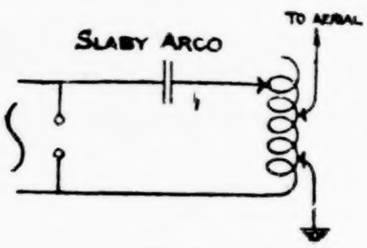


Fig. 29A.

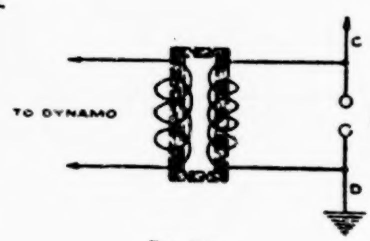


Fig. 29B.

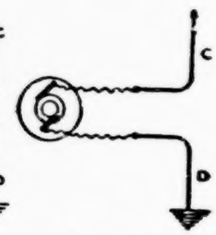


Fig. 29C.

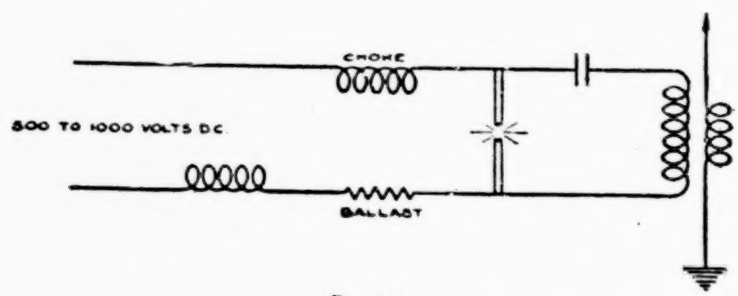


Fig. 29D.

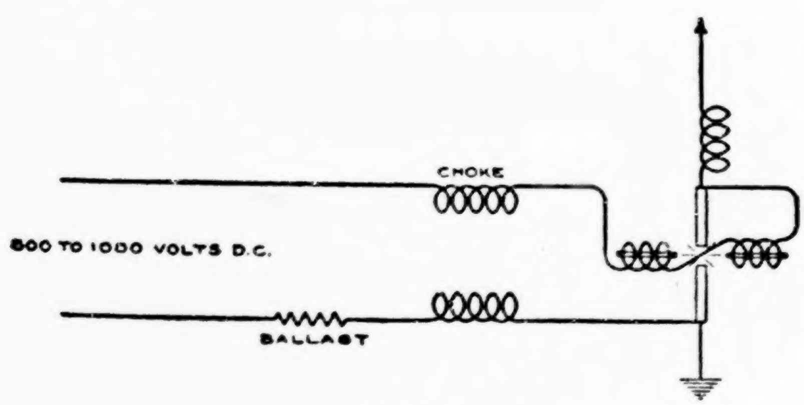


Fig. 29E.

LUFTIN SKETCH P

The Electrician, London, June 11, 1909

The Telefunken or Quenched Spark Discharger. By J. A. Fleming, F.R.S.

In my lecture last Friday evening at the Royal Institution time did not permit me to do more than give a brief description and show one experiment with the multiple small-gap flat plate discharger which has been devised by the experts of the Gesellschaft für Drahtlose Telegraphie for giving practical effect to Prof. M. Wien's method of excitation by shock in spark telegraphy. The methods now in use by that company were being described by Count Arco in a lecture at Cologne at the same hour as my lecture in London, under the title "Das Neue Telefunken System." Although Count Arco had kindly forwarded to me an advance copy of his lecture, I refrained at his request from more than a general statement of the nature of the discharger pending the publication of his lecture in the "Elektrotechnische Zeitschrift."

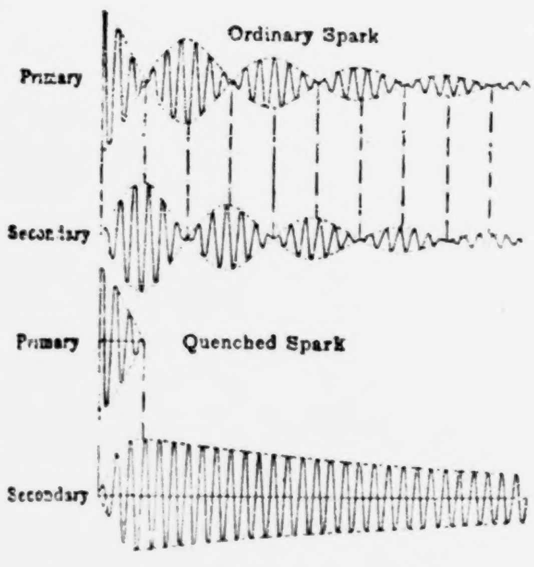
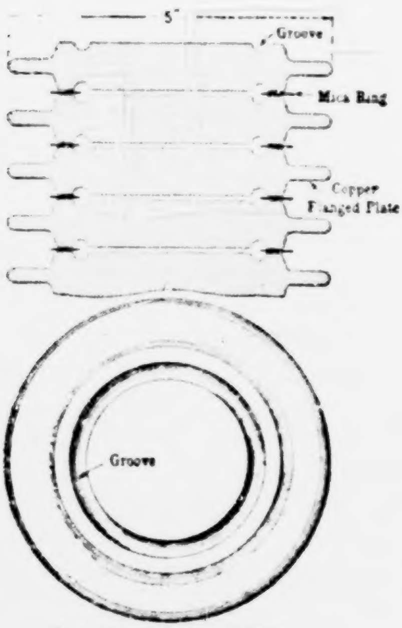


Fig. 1 Oscillations in inductively-coupled circuits.

As there seems to be an impression that the Telefunken discharger and that of von Lepel are identical, it may be well if I describe here, briefly, experiments which I had not time to shown on Friday evening, and which seem to me to prove that the operative principles involved in the two appliances are different. I explained in the lecture that when isochronous primary and secondary oscillation circuits are connected inductively or directly, as long as the spark endures in the primary circuit so long will those reactions take place which result in the production of a complex oscillation in both circuits resolvable into oscillations of two frequencies. I illustrated this by an experiment with two

equal pendulums hung side by side on a loose string, and showed by means of my cymometer that in the similar electrical case of two equal coupled circuits oscillations of two frequencies were present. If time had permitted, it could have been also shown by the cymometer that these two oscillations were present in the primary as well as in the secondary oscillation circuit when using the ordinary spark-gap in the primary. The Telefunken discharger is based [fol. 3467] on the known fact that the damping of very short sparks is extremely large, and that if we can "quench" or stop the primary oscillations after one or two swings the secondary circuit then continues to oscillate freely with a single period, as shown in Fig. 1.

The discharger I used consisted of 12 round flanged plates of copper, 5 in. in diameter, the surfaces being turned true and having a groove in them (see Fig. 2). A mica ring is interposed between each pair of copper plates of such size that the mica half covers each groove. This groove is important, for without it the discharge spark tends to take place always at the edge of the mica. The mica is of such thickness as to make an air space of not greater than 0.01 in. between the flat copper surfaces. In this discharger we have then, say, 11 air gaps, each about 0.01 in. wide and of circular section. When this discharger replaces the ordinary spark-gap in the primary circuit it damps out instantly the primary spark, and hence excites the free oscillations in the secondary circuit by shock. If, then, we place the cymometer alongside of the secondary circuit we find in it oscillations of only one frequency and not two. Also, if we place it alongside the primary circuit, we cannot detect in that circuit any oscillations, because they are so rapidly damped out that they have too small a mean-square value to affect the cymometer or cause the Neon tube to glow perceptibly.



Plan of Copper Flanged Plate

FIG. 2. Plan and section showing portion of discharger.

In consequence of this rapid damping it is possible to employ an alternator having a frequency of 1,000 to 2,000 to create a corresponding number of primary discharge sparks per second, without producing any true arc discharge. The rapid cooling of the discharge surfaces entirely prevents it.

The discs for this purpose are made of copper or silvered copper plates, and in the case of large discharges the discs are made hollow and water-cooled.

The rapid succession of highly-damped primary sparks creates then an equally rapid succession of very feebly damped trains of oscillations in the secondary circuit having a very large mean-square value, and therefore possessing many of the properties of undamped oscillations generated without any true-arc effect. The operation of this discharger seems to me therefore essentially different from one in which an oscillatory arc is created between metal [fol. 3468] surfaces by the employment of a continuous or direct current, neither is its operation dependent on the presence of an atmosphere of hydro-carbon vapour. On the contrary, it may be described as having most perfect arc-quenching properties possible.

The Telefunken discharger could not, therefore, be placed in the circuit of the antenna as is the generator shown in the diagram of circuits in the article describing the von Lepel system in The Electrician of May 14th, whereas that later mode of connection is quite consistent with a performance of a discharger which is essentially an arc method and not a spark method.

Three other properties of the Telefunken discharger deserve notice. It is almost noiseless, and, being entirely enclosed, could be used in an inflamable atmosphere. It seems, therefore, likely to be of use in balloons or airships where an open or naked spark could not be employed. Finally, as the whole of the energy transferred to the secondary circuit expends itself in the production of radiation of one single wave-length it must be more economical than methods which generate waves of two wave-lengths, but capture at the receiver radiation conveyed by only one of these wave-lengths.

Defendant's Exhibit C-5

The Electrician, London, November 10, 1911

The Telefunken System of Wireless Telegraphy

Commercial wireless telegraphy in Germany owed its early progress to two groups of workers—namely, Prof. Braun, of Strassburg, on the one hand, whose wireless telegraph company became amalgamated with Messrs. Siemens & Halske, and, on the other hand, Prof. Slaby and Count von Arco, who were associated with the Allgemeine Elektricitäts-Gesellschaft (more generally known by the abbreviation "A.E.G."). Both these companies carried on a business in wireless telegraphy, but in 1903 the advantages of consolidation became evident, and the two companies combined to form the Gesellschaft für drahtlose Telegraphie m.b.H., Berlin. Thenceforth this Company supplied stations based on the combination of the Braun-Siemens and Slaby-Arco systems, and the resulting system became familiar under the shorter name "Telefunken." As was only to be expected, this amalgamation of interests produced a rapid development.

In what follows we are able, through the courtesy of the Telefunken Company (to use an abbreviated title) to give a complete account of the "singing spark" system and the apparatus with which the Telefunken stations are equipped.

Up to the year 1907 the slow spark was used by the Company (that is, about 20 sparks per second), but in that year the spark frequency was raised, with the result that the range of existing stations became approximately doubled. Since that time, however, a further great change has been introduced by using "singing quenched sparks."

It is well known that when two oscillating circuits are coupled together, the energy sways backwards and for- [fol. 3469] wards from one to the other, and that each circuit emits waves of two frequencies; and this leads to serious inefficiency in practice with the usual spark, because only one of the two frequencies can be utilised. In 1906 Prof. Max Wien contributed an important article to the "Physikalische Zeitschrift," in which he showed that if the oscillations in the primary circuit were stopped as soon as the secondary circuit was oscillating, the latter would continue to oscillate at its natural period, and would therefore emit waves of only one frequency. A much higher efficiency

is, therefore, to be expected with the "quenched spark" than with the ordinary spark.

What takes place is shown graphically in Fig. 1. The two top curves show a train of oscillations in the primary and secondary circuits in the case of the ordinary spark, and it is seen that a maximum amplitude in one corresponds with a minimum amplitude in the other. Instead of the secondary giving a regular train of oscillations with decreasing amplitude it oscillates with "beats," in the same way as beats are heard when two notes of nearly similar pitch are sounded together. In the case of such coupled circuits, by means of a wave meter the two waves can be detected easily; and as a tuned station can only respond to the frequency to which it is turned, only one of these waves can be used, and thus half the energy is wasted. It is true that a single wave is obtained in the two extreme cases of very tight and very loose coupling, but neither of these afford a practical solution.

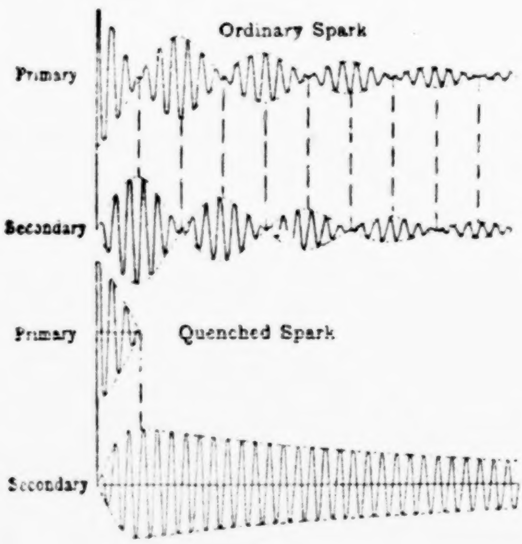


FIG. 1.—Diagram of oscillations in coupled circuits. (a) Ordinary spark, (b) quenched spark.

In the quenched spark system, on the other hand, the spark is quenched as soon as the energy in the primary circuit is a minimum and that in the secondary a maximum. Thus, after quenching, the primary no longer oscillates, and the secondary oscillates with its natural period; so that, under suitable conditions, a feebly damped train is obtained, as indicated in the lower part of Fig. 1.

In all probability many people worked unwittingly with the quenched spark before the appearance of Prof. Wien's Paper, for the conditions for quenching are easily obtained. With ordinary circular electrodes placed close together, or even with quite thin plates placed edge to edge so as to

form a small gap, quenched sparks are obtained and will continue so long as the heat is conveyed away rapidly [fol. 3470] enough. As soon, however, as the electrodes become hot the spark becomes an arc (that is, the metal is volatilised and takes part in the conduction) and quenching no longer occurs. Also a single wave is not obtained unless the spark gap is quite small, as is shown by the curves in Fig. 2 (due to Prof. Wien). If the gap is not very small two waves are obtained, both differing from that of resonance as already mentioned.

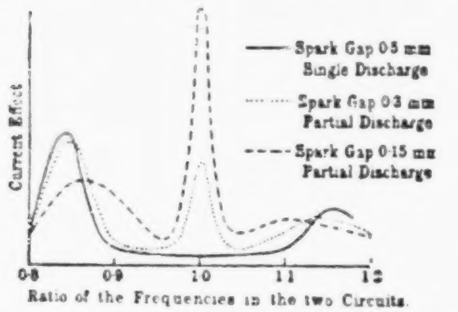


FIG. 2. Curves showing the importance of small gaps in producing a single wave by quenched spark.

In the Telefunken system the exciting circuit containing the quenched spark gaps is coupled either directly or inductively to the syntonised antenna system. The coupling is made sufficiently close that the transfer of energy from the exciting circuit to the antenna takes place quickly, but, on the other hand, the coupling is so loose that quenching begins after the first "beat" oscillation. It is found that the most suitable degree of coupling is 20 per cent., whence it follows that the number of half waves in the primary before quenching occurs (being $1/\delta$) is five. To give the best result it is necessary that the reaction of the secondary circuit should assist the quench-

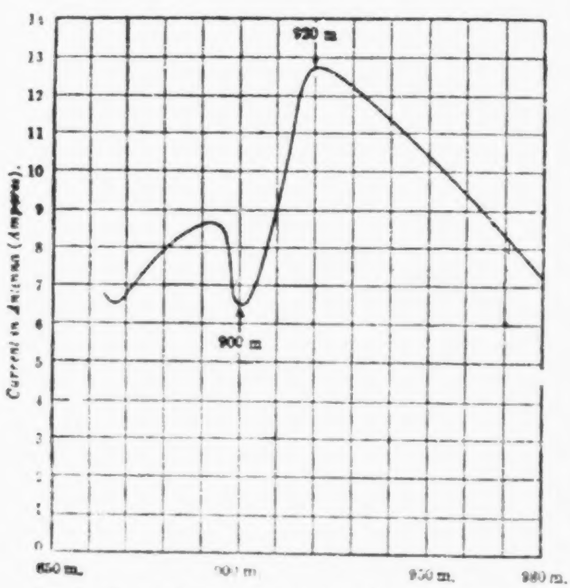


FIG. 3. Curve showing the necessity for slight mistuning. Primary wave maintained constant at 900 metres. Secondary wave varied.

ing in the primary, and for that reason the two circuits are slightly mistuned—namely, to the extent of about 2 per cent. The closer the coupling the greater must be the mistuning. In practice the coupling is varied until an ammeter in the antenna shows a maximum, and in this way two or three maxima can be found, but the best result is obtained with about 20 per cent coupling.

Fig. 3 is an illustration of the effect of tuning. Here the primary wave was kept constant, and it is seen that the maximum in the antenna was not obtained when the circuits [fol. 3471] were in tune; one occurs on each side of the position of syntony, but the best condition appears in this case when the secondary wave length is 920 metres as compared with 900 for the primary.

In Fig. 4 are given resonance curves of the primary, when the secondary wave length is kept constant, for different couplings and primary wave lengths. It will be noticed that the primary wave is of practically the same length as

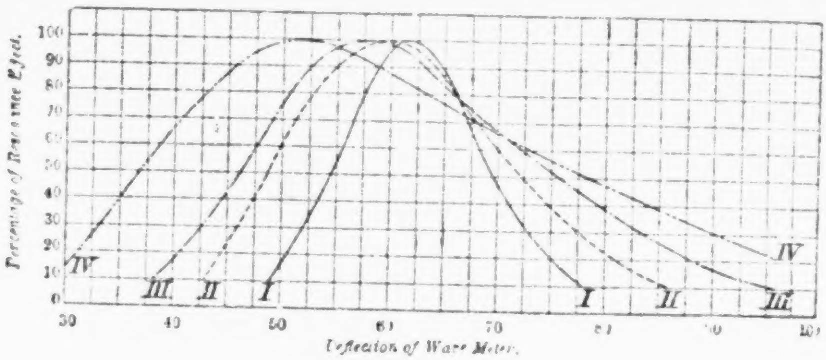


FIG. 4. Resonance curves with quenched spark for various couplings and secondary wave constant.

	Coupling	Primary Wave Length	Secondary Wave Length		Coupling	Primary Wave Length	Secondary Wave Length
I	0.05%	1340	1340	III	9%	1294	1340
II	7%	1312	1340	IV	18.2%	1230	1340

the secondary wave for a very loose coupling, but there is an increasing difference as the coupling is made closer. The curves in this figure are not symmetrical because the wave meter readings were merely deflections, not wave lengths.

Since each spark gives rise to a definite series of oscillations if the quenching is precise, it follows that this system permits the use of a very regular series of sparks. By using

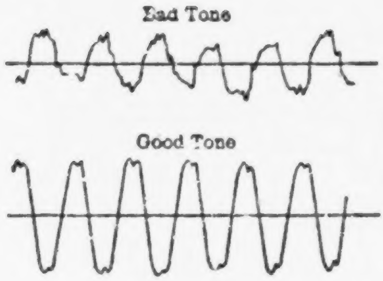


Fig. 5.—Oscillograph records of good and bad tones.

a rapid series a musical note is obtained in the telephone corresponding to the frequency of the oscillation groups or sparks, and this note is very easy to hear. Consequently the quenched spark system has three main advantages:

1. The transmitting apparatus and antennæ are small.
1. The transmitting apparatus and antennæ are small.
2. Large ranges.
3. High speed.

For producing the discharge continuous current might be used, but this has the disadvantage that it tends to give arcs, and high tensions are not produced easily. Further, continuous current would lead to complications in the receiver, and for this reason alternating currents of com- [fol. 3472] mercial frequencies were also discarded. Recourse was, therefore, had to an alternator giving a frequency of 500 (*i.e.*, 1,000 sparks per second). If there is merely one spark per half period a very good tone is obtained. This point is illustrated by the oscillograph records in Fig. 5. In the upper curve three partial sparks take place per half period and the tone is bad, whereas in the lower curve only one discharge per half period takes place. It is necessary to have the alternator circuit nearly resonant. It is not made quite resonant because the spark resistance introduces a variation. Thus the circuit is tuned for, say, 1,300 revs. per min., but the alternator is run at 1,500 revs. per min.

The speed of the alternators that are used can be varied about 50 per cent., and a pure tone can be obtained for each speed. Thus the tone can be varied continuously through half an octave; in addition, there are regulating devices combined with the machine or transformer, by which the

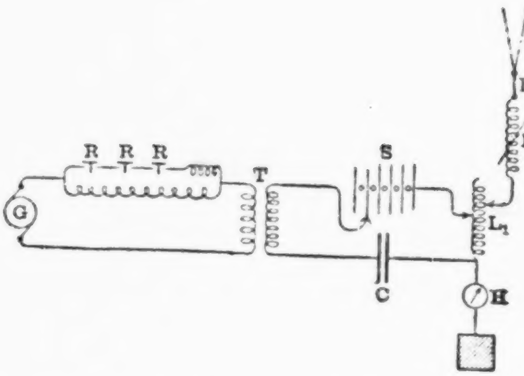


FIG. 6 Diagram of transmitting system.

tone can be adjusted to the lower fifths and to the two lower octaves. These last-mentioned variations, in the case of small stations up to 2 kw., can be effected by depressing keys.

Before describing the component parts of the Telefunken system it may be convenient to refer to Figs. 6 and 7, which show the connections for transmitting and receiving respectively. The alternating current is brought to a transformer, where it is raised to an appropriate pressure (4,000 to 70,000 volts, depending on the size of the station), the secondary being connected with the spark discharger on the one hand and to a capacity on the other. This circuit is coupled either directly or inductively to the antenna. The capacity is not variable in small stations, but may be half cut out in large stations if desired. The antenna contains a variable inductance, and is earthed through an ammeter.

The damping of the waves radiated is about 0.08 to 0.1 with slowly radiating umbrella and *T* antennæ, if the latter are working with their natural wave length, and only 0.05 to 0.03 if the wave length is increased to three or four times the natural length. The period of the high-frequency circuit is absolutely constant, so that, in contradistinction to arc lamp excitation, the resonance can be completely utilised. Owing to the very slight damping of the antenna, intermediate circuits between the exciter and the antenna have not been introduced. The damping of such a circuit [fol. 3473] would have to be one-tenth that of the antenna to work satisfactorily; that is, not more than 0.01 to 0.005. This is difficult to achieve, and would lead to rather com-

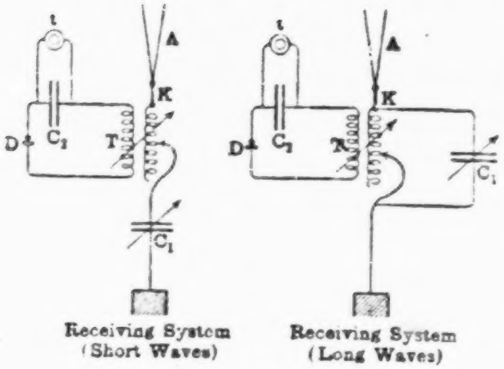


FIG. 7. Systems Used for Receiving.

plicated arrangements. The only cases in which an intermediate circuit may be necessary are when it is impossible to use a standard form of antenna.

For receiving, the antenna is switched over to a transformer, which couples it inductively with a closed receiving circuit. For short waves the primary of this transformer is in series, with a variable capacity and thence to earth. For long wave lengths, on the other hand, the inductance and capacity are in parallel. The secondary of the transformer is taken to the detector and a small fixed capacity in series. Across the poles of this capacity is the telephone.

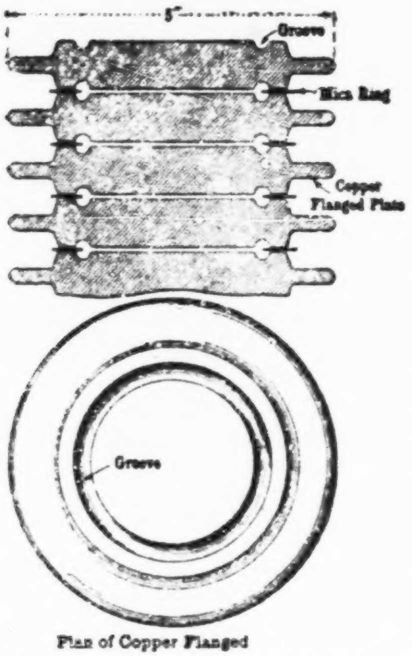


FIG. 8. Section and Plan of Spark Discharger.

Owing to the oscillations in the primary sending circuit persisting for only a short proportion of the whole time, the primary losses are not so important as usual, and therefore paper condensers are often used instead of Leyden jars, a number being connected in series. Further, brush discharges from the edges of the condensers do not occur nearly so much as in the case of slowly quenched circuits, doubtless because local ionisation is reduced.

Inductances for the smaller stations are made of finely-stranded wire, but for the larger stations copper strip is used in the form of flat spirals. In the case of wound inductances very fine specially enameled copper wire is used to keep down the eddy

(Here follows 1 photolithograph, side folio 3474.)

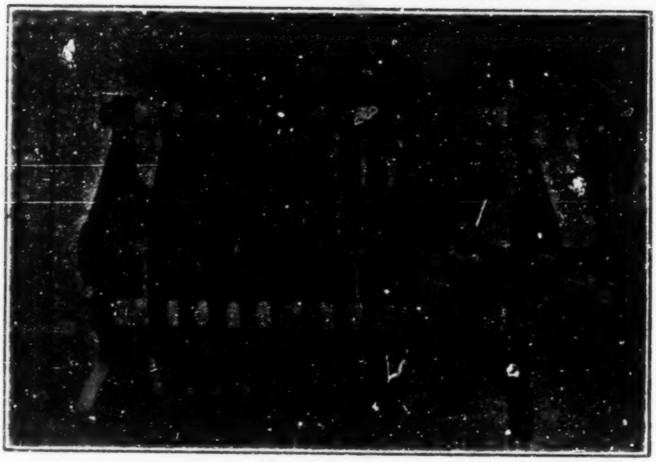


FIGURE 9.—VIEW OF SPARK DISCHARGER.

FIGURE 11.—ARRANGEMENT FOR TESTING DETECTORS

current loss to a minimum, and as the resistance must be very low to correspond with the antenna, and since large currents are used, as many as 10,000 to 20,000 separate insulated wires are sometimes run in parallel. Since all such wires should carry the same current, special windings are employed by which each wire has the same resistance and inductance.

[fol. 3475] *The Spark Discharger.*—A section of the spark discharger as now used by the Telefunken Company is shown in Fig. 8. It consists of circular plates of copper, each faced with a plate of silver, which is ground dead true except that it is slightly recessed at the centre. There is a groove some distance from the centre and the metal plates are separated by mica rings to a distance of 0.2 mm. The spark forms at any point of the flat surface; it is then forced towards the periphery in a radial direction by the electromagnetic field, and is eventually extinguished on its path. A number of these spark-gaps are held in series, as shown in Fig. 9. It will be noticed that between each pair of these discs is a larger disc of thin copper, which is effective in radiating the heat generated by the spark. These radiating discs are carried by three porcelain tubes, and these tubes are so placed that the inner discs can rest upon the two lower tubes. Thus it is a very easy matter to take a disc out or to replace it. The spark gaps are pressed together in the frame by means of a screw, and the insulation provided at each end consists of short glass cylinders. The whole arrangement, as is shown by the illustration, is very compact and serviceable. Short-circuiting plugs, which are simply "U"-shaped pieces of metal, are provided, in order to short-circuit as many gaps as may not be required. Two of these are seen in position in the illustration. By connecting a suitable number of gaps in series it is possible to keep the energy per gap from exceeding a certain value, and thus to prevent overloading. Since the energy transmitted varies as the square of the number of spark gaps the regulation by short-circuiting covers a wide range. Thus if there are 10 gaps and 9 are cut out, the maximum energy is reduced to 1 per cent. In the case of small dischargers

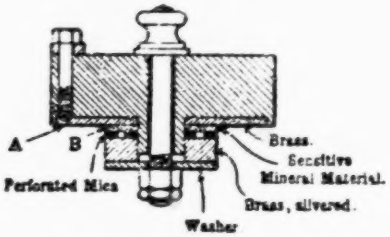


FIG. 10.—Section of detector.

point of connection of the circuit to the discharger is made variable and short-circuiting clips are not used. The pressure per gap is 1,200 volts.

Water cooling is not adopted, but dischargers are sometimes used with air ducts, and the radiating discs are also varied in size according to requirements.

The Detector.—Since the waves to be received are intermittent but rapid, so called integrating or contact detectors are chiefly employed for receiving, the contact being between a mineral and graphite or a metal. A high-frequency safety device is employed to protect the detector in case of sudden overloads.

The construction adopted will be understood by reference to Fig. 10, which, however, is not to scale, though roughly full size. From this it will be seen that the essential parts are a washer of brass, A, as one terminal, against which is pressed a sensitive mineral washer. The desired pressure is obtained by screwing down a second brass washer B (which may be regarded as the other terminal), through [fol. 3476] a mica washer which is perforated with a number of holes. The surface of B next the mica is corrugated and silvered, and it will be realised that the pressure necessary to secure contact between B and the mineral must be considerable. In fact, to anyone having the idea that the detector is a delicate piece of apparatus, the rapidity and ease with which these detectors are assembled and adjusted in the laboratories of the Telefunken Co. comes as a surprise.

The detectors are adjusted by mounting them inverted in a block, as seen in Fig. 11, and adjusting the nut until comparison with a standard detector is satisfactory. A complete detector is seen to the left of this illustration. In the laboratory, detectors are not only adjusted for sensitiveness, but are also adjusted to an internal resistance best suited to the coupling conditions of the receiver; further, they are tested for about 100 times the working intensity and are submitted to a vibration test.

The detector is used without an auxiliary battery and rectifies the alternating impulses into a pulsating continuous current. With a telephone as a receiver there is a distinct advantage in having these impulses of a regular frequency, because the diaphragm will then respond most readily and give a musical note, whereas irregular disturbances, even of considerably greater energy, will produce no appreciable

effect. In fact the higher the tone the more sensitive the telephone, and the less trouble is there from atmospheric disturbances. A galvanometer, on the other hand, would give the mean detector current, and its deflection would increase with the energy irrespective of the regularity of the impulses. The musical tone is very easily distinguished, and if pure it can be heard quite clearly even when very weak. A range of tones of about 200 to 2,000 vibrations per second is obtainable, and various tuned transmitters can be easily distinguished from each other. The musical tone is thus important, the more so in that it is not readily confused with atmospherics.

Receiving set.—The receiving set is very compact, and is shown well in Fig. 12. At the back is seen the antenna switch, and when this is thrown over for receiving, the antenna is connected to the primary coil of the coupling transformer. On the other hand, when this switch is open for sending, the circuit is automatically broken on each side of the detector and also the telephone circuit. One of these primary coils is shown in position, and two more are seen along side the apparatus. The inductance in the antenna can be varied in three steps for each coil by means of a plug which can be inserted into any one of the three holes on the face of the coil. Since two or more coils are provided, and these can be easily interchanged, a large range of inductance is available. The primary is connected in series or in parallel with the capacity and thence to earth. The capacity is of the usual air type with semicircular plates and is continuously variable by turning the knob seen in the illustration.

(Here follows photolithograph, side folio 3477)

3910A

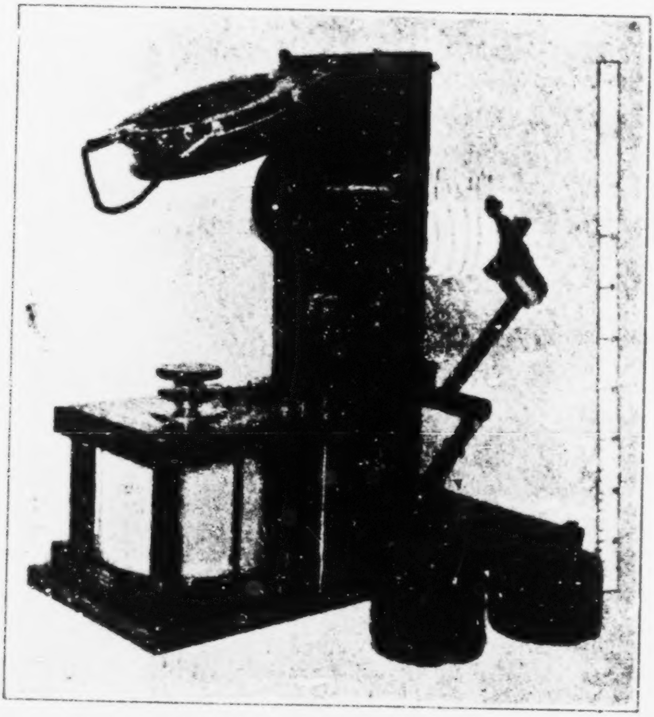


FIGURE 12. RECEIVING SET.

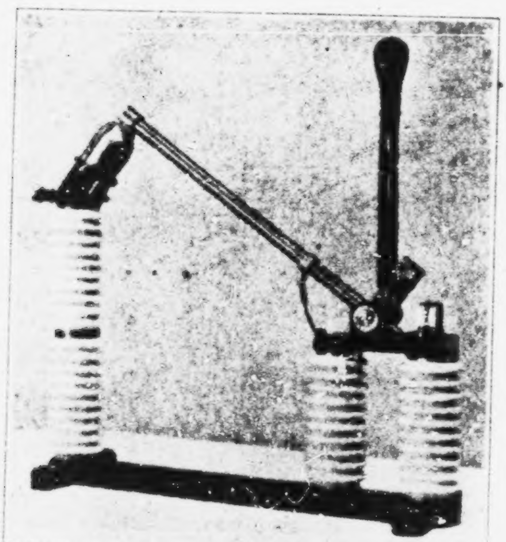


FIGURE 13. ANTENNA SWITCH.

The secondary of the transformer can be moved outwards, as it is hinged, and when it is moved outwards to the horizontal position it can also be turned round upon a [fol. 3478] horizontal axis. Consequently, the coupling can be varied between extreme limits. The inductance in the secondary can also be varied in six steps by changing the position of the plug, which is seen at the end of a flexible connection. A small switch will be noticed below the coupling transformer. The object of this is to connect the inductance and capacity in series for receiving short waves and in parallel for receiving long waves. The detector is seen below the switch, and terminals are provided for connecting up the telephone or call apparatus as desired. A continuous wave range of 250 to 2,500 metres is covered by turning the condenser and by a single interchange of coupling coils.

Since the energy from the antenna is transferred from the coupling coil of the antenna to an aperiodic circuit containing the detector, the receiving antenna alone requires syntonising, and this is effected simply by turning the condenser. Owing to the smallness of the damping of the quenched spark waves, very exact tuning is obtainable.

When stations have highly damped antennæ of large capacity, this simple arrangement cannot be adopted because the enormous atmospheric disturbances met with in the case of large antenna are carried with almost their full force to the detector, causing serious reduction in its sensitiveness and often damaging it. This difficulty is obviated by the use of a very weakly damped intermediate circuit, which is coupled very loosely with the antenna, and not too closely with the detector circuit.

For stations above a certain size a separate antenna switch is used, as shown in Fig. 13. With the switch down, as seen in this illustration, the antenna is connected for receiving, and when it is pulled over to the right, connection is made for transmitting.

(To be continued.)

Defendant's Exhibit D-5

Wireless Telegraphy, by Zenneck, 1915

* * * * * * *

Whenever the coupling is fairly close, K^2 is considerably greater than $\left(\frac{d_1-d_2}{2\pi}\right)^2$, so that the quantity K' is not much different from the coupling coefficient K. (See note †, p. 87.)

Under these conditions there are in general [57] two distinct oscillations the so-called "coupling oscillations" (coupling waves") produced *in both the primary and the secondary circuit*, having *two distinct frequencies*, N^I and N^{II}, *and two distinct decrements*, d^I and d^{II}.

If, as heretofore, we use I_1 and V_1 to indicate current and voltage in the primary circuit, I_2 and V_2 the same in the secondary then I_1 (and V_1) as well as I_2 (and V_2) are the results of two oscillations. Hence we may write:

$$\left.\begin{aligned} I_1 &= I_1^I + I_1^{II} \\ V_1 &= V_1^I + V_1^{II} \end{aligned}\right\} \text{for the primary circuit.}$$

$$\left.\begin{aligned} I_2 &= I_2^I + I_2^{II} \\ V_2 &= V_2^I + V_2^{II} \end{aligned}\right\} \text{for the secondary circuit.}$$

[fol. 3479] The various oscillations have the following frequencies, wave lengths and decrements:

$$\left.\begin{aligned} &I_1^I \text{ (and } V_1^I) \\ &I_2^I \text{ (and } V_2^I) \end{aligned}\right\} N^I, \lambda^I \text{ and } d^I$$

$$\left.\begin{aligned} &I_1^{II} \text{ (and } V_1^{II}) \\ &I_2^{II} \text{ (and } V_2^{II}) \end{aligned}\right\} N^{II}, \lambda^{II} \text{ and } d^{II}$$

59. *The Frequency of Coupling Waves. a. Primary Circuit without Spark Gap.*—Let the index I refer to the oscillation having the higher frequency and shorter wave length. Then we have [57]:

• • • • • • •

Hence, the greater K', *i.e., the closer the coupling, the more will the frequencies (wave-lengths) of the coupling waves differ from each other and from the original common frequency (wave-length)*.

b. Primary Circuit with Spark Gap.—In this case also the relations between the frequencies before and after coupling are of the *form* of equations (1). It is not definitely known, however, though this is of no practical importance, whether the factor K' has the relation to the coefficient of coupling, K, and the decrements given by equation (1) of Art. 58. The quantity which actually determines the extent of the coupling and which may be directly measured by test [Art. 87] is the factor K' for circuits with spark gap also.

K' is called the "degree of coupling." Its value is frequently expressed in percentage, thus: "3 per cent. coupling" means $K'=0.03$. The relation between N', N'' and N, as well as λ', λ'' and λ is given in Table X for different values of K'.

c. The *resultant oscillation* produced from the two coupling oscillations of different frequency is of the form shown diagrammatically in Fig. 130, and shown in Fig. 124 as obtained with an oscillograph (H. DIESSELHORST [illegible]) and in Fig. 125 as photographed from the spark discharges (H. RAU [illegible]). The resultant oscillation may be conceived as having the frequency N and an amplitude which periodically increases and decreases, similarly to the *beats* or *pulsations* of a tone which are observed in acoustics.

(Here follows photolithograph, side folio 3480)

FIGURE 124

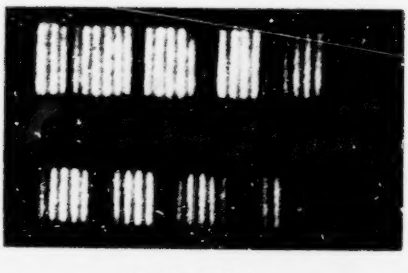


FIGURE 125

The greater the difference between the frequencies of the two oscillations, *i.e.*, the closer the coupling, the greater is the number of pulsations obtained per second. This number, S, which is the number of times per second that the amplitude passes through zero, is given by

$$S = N^{I} - N^{II} = \text{approx. } NK'$$

Hence the duration of one beat or pulsation is approximately $= \frac{1}{NK'}$ seconds $= \frac{1}{K'}$ periods.

d. The *energy relations*, as is evident from Fig. 130, are as follows: Originally the entire energy resides in the pri- [fol. 3481] mary circuit. After half of one pulsation the amplitude of the oscillation in the primary circuit is zero, while that in the secondary is a maximum and the entire energy has been transferred to the secondary circuit. After another half pulsation all the energy is again back in the primary and the secondary is at zero, etc., etc. In short, the energy continues to swing back and forth between the primary and secondary circuits.

60. *The Decrements of the Coupling Waves.—a. Primary Circuits without Spark Gap* (P. Drude[59]).—The relations of the decrements before and after coupling are expressed by:

$$\left.\begin{aligned} d^{I} &= \frac{d_1+d_2}{2}\,\frac{N^{I}}{N} = \frac{d_1+d_2}{2}\,\frac{\lambda}{\lambda^{I}} \\ d^{II} &= \frac{d_1+d_2}{2}\,\frac{N^{II}}{N} = \frac{d_1+d_2}{2}\,\frac{\lambda}{\lambda^{II}} \end{aligned}\right\} \frac{d^{I}}{d^{II}} = \frac{N^{I}}{N^{II}} = \frac{\lambda^{II}}{\lambda^{I}}$$

So that while for low degrees of coupling the decrements of the two oscillations are approximately equal to the average value of the decrement before coupling, *as the coupling becomes closer, the decrement of the oscillation having the shorter wave-length increases and that of the oscillation having the longer wave becomes less than the average value mentioned above.*

Theoretically the closest possible coupling exists when $K'=1$; in practice about the highest value obtainable is approximately $K'=0.6$. For this latter value, we have:

$$\begin{aligned} N^{I} &= 1.6\ N & \qquad d^{I} &= 0.8\ (d_1+d_2) \\ N^{II} &= 0.8\ N & \qquad d^{II} &= 0.4\ (d_1+d_2) \end{aligned}$$

Hence in practice the frequency and decrement of the oscillation of shorter wave-length will at most be twice what they are for that of the longer wave.

b. Primary Circuit with Spark Gap. (C. Fischer [90]).—In this case the relations of *a* do not hold.

1. The decrements of both oscillations, particularly if the coupling is loose, are greater than would follow from *a*.

2. It is by no means always the oscillation of shorter wave-length which is the most highly damped. *On the contrary, this usually is more slightly damped than the oscillation of greater wave-length.*

The conditions obtained by coupling a condenser circuit containing a spark gap with another having no gap, were observed by C. Fischer, whose results are shown in Figs. 126 and 127. Fig. 126 refers to the case of primary and secondary capacities being practically equal [1] while in Fig. 127 [2] the capacity in the primary circuit is much greater than that in the secondary.

61. *Amplitude and Phase of the Oscillations* [91]—*a. Amplitude.* [3] The current amplitudes of the individual oscillations have the same relation, approximately, as their frequencies, *i.e.*,

$$\frac{I^{I}_{1}}{I^{II}_{1}} = \frac{I^{I}_{2}}{I^{II}_{2}} = \frac{N^{I}}{N^{II}} = \frac{\lambda^{II}}{\lambda^{I}}$$

[col. 3482] *The current amplitude of the oscillation having the shorter wave-length is therefore greater than that of the longer wave oscillation.*

Assume a given known value for the initial potential V_{10} of the primary circuit, then we have the following expres-

[1] $C_1 = C_2 = 0.85 \times 10^{-3}$ MF. $L_1 = L_2 =$ approx. 22,000 *C.G.S.* Length of gap = .6 mm.

[2] $C_1 = 5.29 \times 10^{-3}$ MF. $L_1 = 6230$ *C.G.S.* Gap = 6.8 mm. approx. $C_2 = 0.45 \times 10^{-3}$ MF. $L_2 = 73{,}000$ *C.G.S.*

[3] If the current in one of the circuits is not quasi-stationary, the current amplitude is to be understood as the value at the current anti-node.

sions for the current and voltage amplitudes in a secondary circuit having quasi-stationary current:[4]

* * * * * * *

b. Phase. If we consider as positive the direction of the oscillating current I (one) in both circuits, the vector dia-

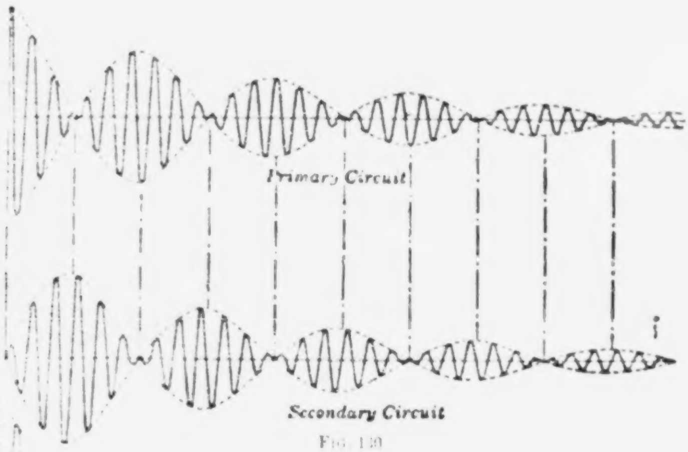


Fig. 130

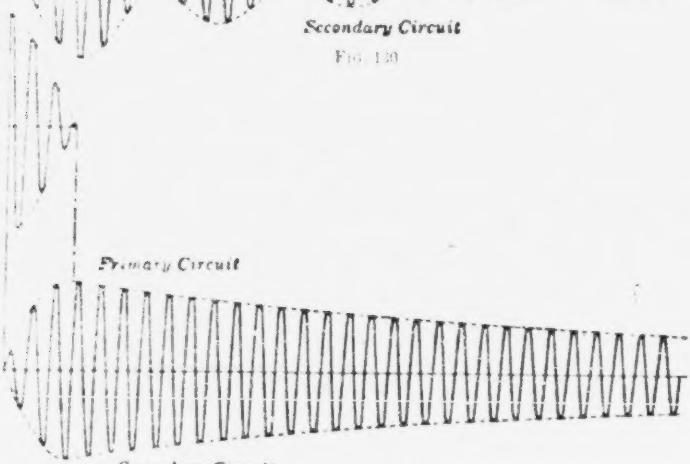


Fig. 131

gram will have the form of Fig. 128. The angles of phase displacement φ' and φ'' are given approximately by

* * * * * * *

[4] If neither primary nor secondary circuit has quasi-stationary current, these relations, to the extent of their involving the voltage, hold only approximately; those independent of U_2 are correct if the value of the current antinode is taken as the current amplitude.

In all practical cases, as long as the coupling is fairly close[5] these angles are very small. We may therefore state roughly: *of the oscillations in the primary and secondary circuits having the same frequency,*

. . . .

the one pair (I_1^I, *and* I_2^I[6]) *are almost in phase, while the other pair* (I_1^{II}, *and* I_2^{II}[6]) *are approximately* 180° *apart.*

c. The maximum amplitude of the resultant oscillation in the secondary circuit depends not only upon the amplitude of the two component oscillations, but also upon their phase and damping.

4. Quenching Action in Coupled Circuits (M. Wien[92])

62. *Form of the Oscillations.*—In Art. 59 it was stated that under the conditions therein specified the oscillations in the primary and secondary circuits would be of the nature illustrated in Fig. 130.[7] In the primary circuit, after lapse of half a pulsation, the amplitude of the oscillation is zero or nearly zero. It then increases again, this being due to the fact that the secondary, whose amplitude is at its maximum at that moment, induces an EMF in the primary, producing a difference of potential between the electrodes of the spark gap.

The conditions may be such, however, that the spark gap, during the time in which the amplitude in the primary circuit is very small, becomes so deionized, that the EMF induced by the secondary is no longer sufficient to start or "ignite" a spark discharge across the gap. As a result the spark gap remains quenched (whence the terms "quenching action" or "quenched gap." The oscillations in the primary then discontinue entirely and the secondary circuit continues to oscillate with its natural damping and at its natural frequency just as if the primary circuit did not exist. Compare the diagrammatic Fig. 131[8] and the spark photograph Fig. 132 (H. Rau[93]).)

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[5] Assume $d_1 = 0.08$ and $d_2 = 0.2$; then K' need only be large as compared to 0.02. If the secondary circuit is less damped the conditions become still more favorable.

[6] i is used in Fig. 128 instead of the capital I.

[7] Assumption: $d^I = d^{II} = 0.08$; $K' = 0.16$.

[8] Assumption: $d_1 = 0.03$; otherwise just as for Fig. 130.

(Here follows 1 photolithograph, side folio 3483)

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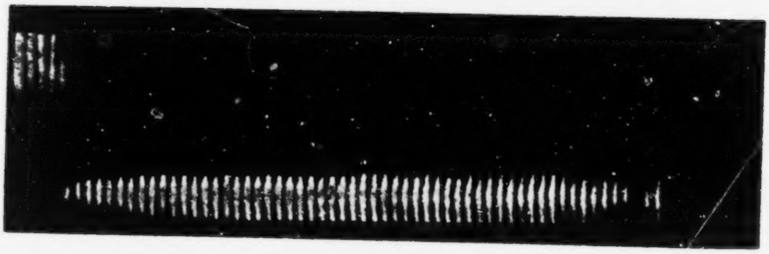

FIGURE 132.

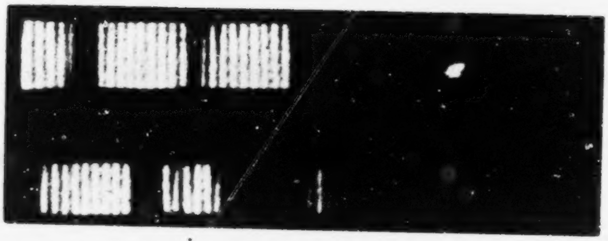

FIGURE 133

[fol. 3484] 63. *Various Types of Quenched Gaps.*—*a. Very short metallic spark gaps* (M. WIEN) are of special importance in practice.

Not only the *material* of which the electrodes are made but also the *gas* in the gap between them is of importance. Particularly good quenching action is obtained with silver and copper, aluminium is less satisfactory and zinc, tin and magnesium do not give good quenching (M. WIEN[92]); platinum-iridium alloy is also quite effective with short gap lengths (H. BOAS[93]). The quenching action is increased if the sparks are passed through *hydrogen* instead of air (*A. Espinosa de los Monteros*[94]).[9]

b. For laboratory purposes the so-called *mercury-arc lamp*, i.e., an exhausted glass tube with mercury electrodes (R. RENDAHL[95]) is very well adapted. Apparently the only essential element in the form of this lamp is the provision of a sufficiently large space over the electrodes for cooling and condensing the mercury vapor. Moreover the tube must have a high vacuum and pure mercury must be used.

c. With primary circuits having long gaps, which in themselves would have no quenching action, it is possible to [fol. 3485] secure quenching by greatly increasing the damping of the primary circuit through an inserted resistance, or better still, by inserting a glass tube filled with gas at very low pressure (*e.g.*, 3 mm. mercury) and having metallic electrodes—a so-called "quenching tube" (M. WIEN[96]).

64. *Requirements for Good Quenching.*—*a. Time-lapse of One Pulsation.* In view of the fact that the primary circuit consumes less energy the sooner the oscillations in it are quenched,[10] *i.e.*, for the sake of efficiency, it is desirable to make the coupling as close as possible. The closer the coupling, the shorter will be the time-lapse or duration of one pulsation, which is the time during which the primary circuit remains active [59*c*].

On the other hand, however, the time during which the amplitude in the primary remains very small and, hence, the time during which the spark gap is subjected to deioniza-

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[9] In regard to hydrogen quenched spark gaps [see Art. 109*c*].

[10] For the same decrement; this also affects the efficiency [*b*].

tion becomes shorter as the coupling is made closer. If this time is made too short, "pure" quenching is no longer obtained, *i.e.*, the primary oscillation is not suppressed after one-half a pulsation. Either coupling oscillations result or intermediate conditions between distinct coupling oscillations and pure quenching are obtained; thus the primary oscillations disappear only after one and one-half or two and one-half pulsations (Fig. 133, H. RAU[33]).

Hence close coupling is desirable for efficiency, while loose[34] coupling is needed for pure quenching. It follows that for every spark gap there must exist a "critical degree of coupling," at which pure quenching is still just obtainable. This is of course always used in order to secure as high efficiency as possible. The higher the critical percentage of coupling, the better will be the quenching action of the given spark gap.

b. Pureness of the Pulsations. It is most favorable for the quenching action if the amplitude of the resultant oscillation in the primary circuit really becomes *zero* after the first half pulsation, that is, if the pulsations are *pure*. The essential condition for this, however, is that both oscillations, after half a pulsation, have the same amplitude but are opposite in phase.

Whether this condition obtains depends upon the accuracy of the tuning between the primary and secondary circuits; the more exact the tuning, the purer will be the pulsations, other things being equal. Moreover, even with perfect tuning, it is evident that the pureness of the pulsations depends upon the initial amplitude of the two oscillations and their *decrements*. In this connection, therefore, the decrement of the primary and secondary circuits becomes of importance. As the decrements of the coupling oscillations also depend on the degree of coupling, the latter affects the quenching action in this way also.

Apparently this effect of the degree of coupling plays a part in connection with the following phenomenon (H. RIEGGER[7]). If the degree of coupling is gradually increased a *first* critical coupling is reached, beyond which pure quenching is no longer attainable. If, however, we proceed to make [fol. 3486] the coupling much closer, a degree of coupling is reached at which pure quenching is again obtained (*second* critical percentage of coupling). In fact, under certain conditions, a *third* critical coupling may occur. The critical de-

gree of coupling of a quenched gap is therefore by no means always a single definite quantity.

The pureness of the pulsations probably also plays a part in the explanation of the fact that by bringing the primary and secondary circuits slightly out of resonance, a pure quenching can be obtained, after the quenching had been spoiled with primary and secondary entirely in tune (H. Riegger [7]).

c. The magnitude of the EMF induced in the primary by the secondary circuit is also affected by the degree of coupling: in fact, is proportional to the coefficient of coupling, other things being equal. Hence the greater the coefficient, so much greater is the danger that a discharge will pass across the spark gap after half a pulsation.

d. Lastly, the *temperature of the electrodes*, that is, not the average temperature, but the maximum at any point (*local heating*) affects the quenching, as when the temperature becomes very high the gas is highly ionized, thereby greatly reducing the quenching action as well as the discharge voltage. This makes it easier for another spark to jump across the gap after the first half pulsation. Hence, care must be taken that the temperature does not rise too high at any part of the gap electrodes.[96]

65. *Concerning the Nature of the Quenching Action.—a.* The general requirement for the best quenching action is identical with the requirement for the quickest possible deionization of the spark gap. The deionization may have several causes, viz.:

1. The *recombining* of the positive and negative ions; when two ions of opposite charge collide, this may result in a neutralization of their charges.

2. *Diffusion* of the ions from the gap space between the electrodes into space without; just as a gas (*e. g.*, illuminating gas), pouring out from some opening will spread out in all directions (diffuse) in the surrounding medium (*e. g.*, air), so the ions diffuse from the space in which they were formed into the surrounding gas.

3. *Absorption* of the ions at the gap electrodes. If an ion comes close to a piece of metal, the latter will have the same

effect upon it as any uncharged conductor has on a charged body, viz., an attractive force. Consequently the ion comes into contact with the metal and gives its charge up to it.

This last kind of deionization is also influenced by the diffusion of the ions. The faster new ions are diffused from the outer space to the surface of the gap electrodes, the quicker will deionization take place, corresponding to a greater coefficient of diffusion.[11]

4. *Deionization by the Electric Field between the Gap Electrodes.*—If an electric field exists betwen the gap elec- [fol. 3487] trodes, the positive ions are attracted to the negative electrode, the negative ions to the positive electrode, where they give up their charge. In the case in point a field

. . . .

[11] The coefficient of diffusion D is defined as follows: If c' is the concentration factor (=change in the number of ions present in 1 cc., along a length of 1 cm.), then the number of ions diffused through a section 1 cm. sq. per sec. is Dc'.

Table IV. (Continued)

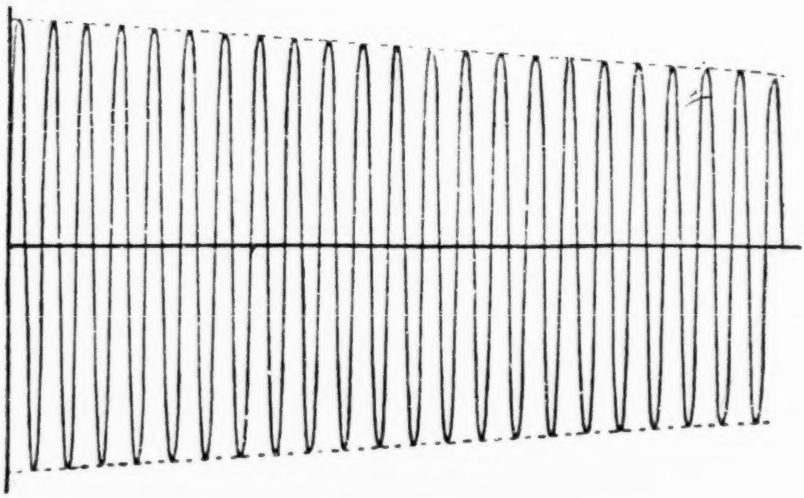


Fig. 464.—$d = 0.01$

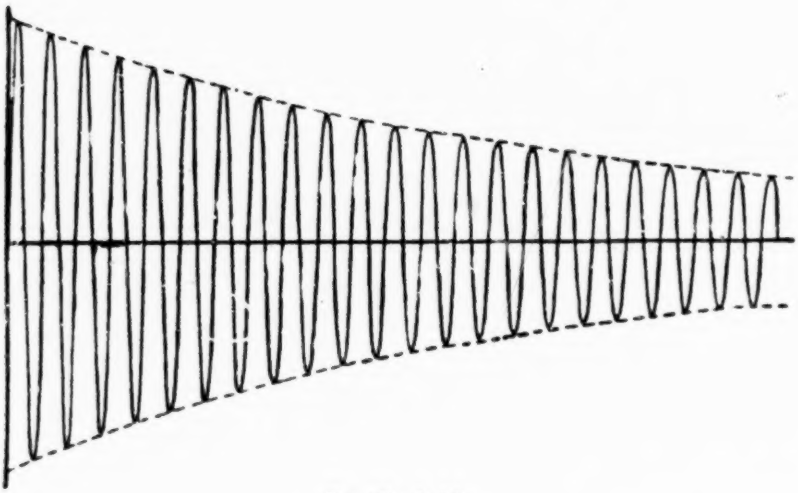


Fig. 465.—$d = 0.0$[illegible]

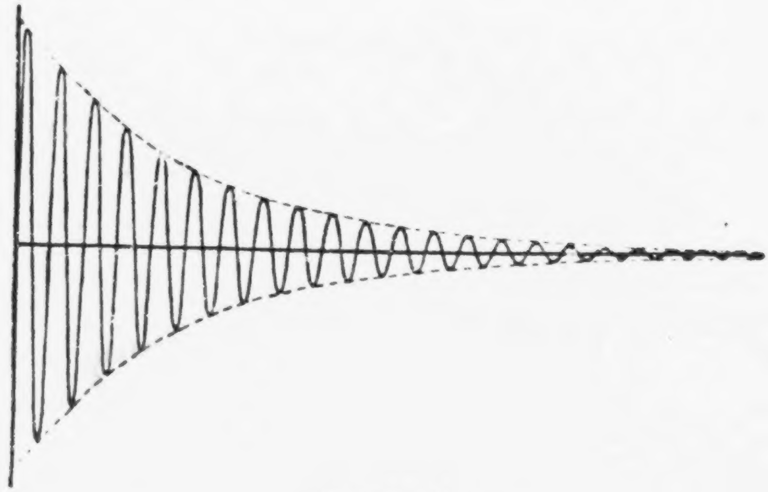


Fig. 466.—$d=0.2$

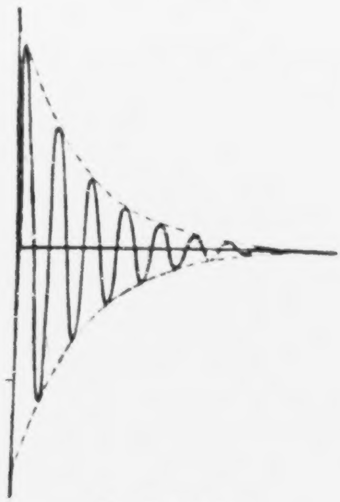


Fig. 467.—$d=0.5$

DEFENDANT'S EXHIBIT E-5

Wireless Telegraphy and Telephony, by Eccles, 1918

Quenched Spark Methods—General Account of the Phenomena. Probably all short spark dischargers set their circuits into oscillation by what is variously called "impact" or "shock" excitation; and the terms "short spark" and "quenched spark" are often taken to be synonymens. Max Wien published in 1906 the first full account and explanation of the phenomenon. His explanation is expressed

diagrammatically in Fig. 110. The two curves (*a*) show the beating oscillations (on a time base) produced in a tuned pair of coupled circuits by a persistent spark in the pri-
[fol. 3489] mary; the curves (*b*) show how the quenching of the spark at an early stage leaves the secondary circuit in possession of all the energy and free to vibrate with its natural frequency. The damping of the primary should be at least ten times that of the secondary. Thus quenching ensures singleness of frequency. Quenched sparks are

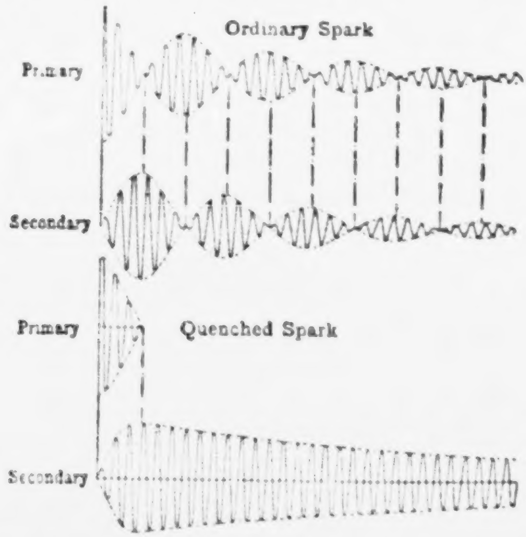


FIG. 110.—Diagram of oscillations in coupled circuits. (*a*) Ordinary spark. (*b*) Quenched spark.

easily obtained by putting two electrodes close together and providing for the rapid removal of heat from the region of the spark. If the metal is allowed to get hot some volatilisation takes place and an arc is established. The importance of size of gap is shown by the resonance curves of

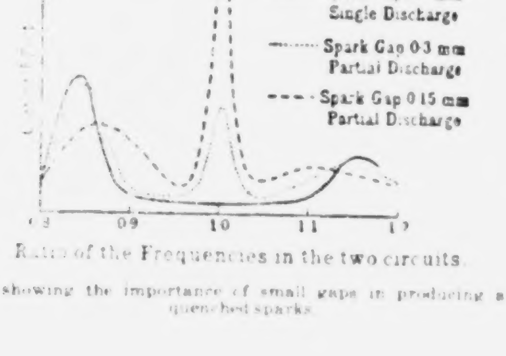


FIG. 111.—Curves showing the importance of small gaps in producing a single wave by quenched sparks.

Fig. 111, which were obtained by Wien using a pair of flat parallel circular brass plates.

The condenser used in shunt to short sparks is usually large. It should be so large that its discharge current across the gap is sufficient to annul the supply current and relight the spark in the opposite

[fol. 3490]

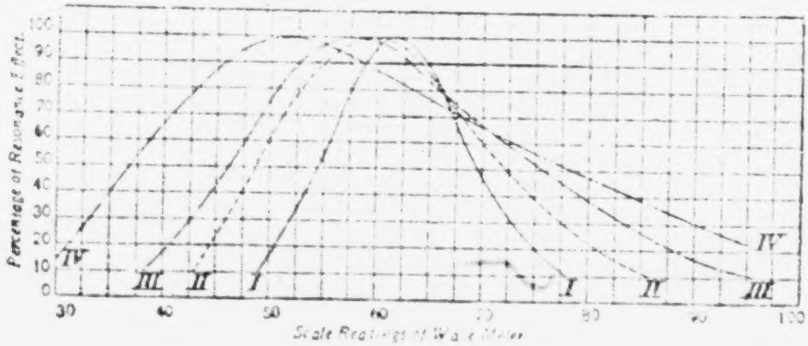


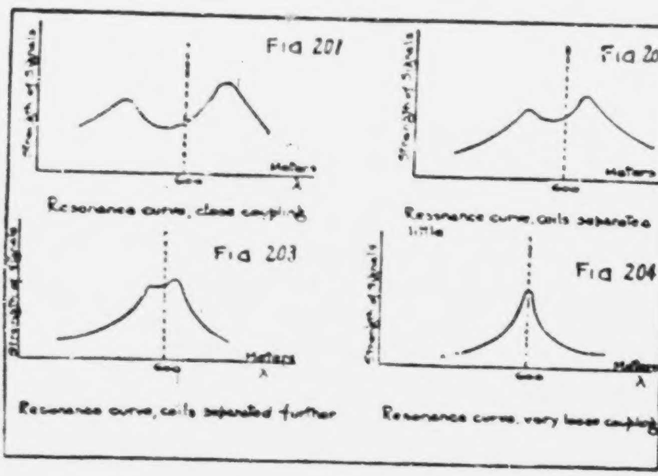
Fig. 112. Resonance curves with quenched spark for various couplings, secondary wave constant.

	Coupling	Primary Wave Length	Secondary Wave Length		Coupling	Primary Wave Length	Secondary Wave Length
I	0.05%	1340	1340	III	9%	1294	1340
II	7%	1312	1340	IV	18.2%	1230	1340

Defendant's Exhibit F-5

Principles Underlying Radio Communication, 1922

In Fig. 204 the signals are strong at or near only one wave length, and diminish rapidly if any of the apparatus adjustments are changed. This is said to be a "pure"



wave.[1] It is desirable to have as sharp a resonance curve as possible, and hence loose coupling is the rule when a plain gap is used. The advantage is that all the power sent out is concentrated into a narrow range of wave lengths, and that receiving stations can tune to the one wave length emitted [fol. 3491] by the transmitting station which they desire to receive and exclude all other wave lengths from other transmitting stations.

Action of the Quenched Gap; Relation to Coupling.—Refer again to the inductively coupled apparatus of Fig. 195 and to the waves of Fig. 154 in Chapter 3. Also refer to the description of the quenched gap in Section 156. The action of the quenched gap is to open the primary circuit, by suppression of the spark at the end of its first train of waves (point *D* in Fig. 154). This prevents the secondary from inducing oscillations in the primary again; that is, from giving energy back to the primary. The secondary or antenna oscillations are not thereafter interfered with by the primary and the antenna goes on oscillating until the energy is all dissipated as waves or heat (see Fig. 155). The length of the train will depend only upon the decrement of the antenna circuit. By reducing the resistance, the dielectric losses, the brush discharges and leakage, the antenna current may be made to oscillate for a comparatively long time, at the frequency for which the set was adjusted. This quenching of the primary avoids the double waves of Figs. 201, 202, and 203, even with close coupling. In fact, the coupling should be close for good operation with the quenched gap. Some care has to be taken in the adjustment of the coupling, but when adjusted properly this gap gives a high pitched, clear note. The wavemeter will readily show when a single sharp wave is obtained (see Section 168), and the sound in the telephone receiver will indicate the proper adjustment for good tone. The quenched gap

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[1] The United States radio law requires that if a transmitting station emits more than one wave length, the energy in no one of the lesser waves shall exceed one-tenth of the energy in the principal wave. See the pamphlet, "Radio Communication Laws of the United States," issued by the Bureau of Navigation, Department of Commerce. Copies may be secured from the Superintendent of Documents, Government Printing Office, Washington, for 15 cents each.

is very efficient because the close coupling produces a large current in the antenna.

It is well to note that the principles of operation of the quenched gap and plain gap are exactly opposite. The former aims to stop the primary oscillations quickly, after the secondary has been brought to full activity. The latter aims to keep the primary oscillations going as long as possible, all the time giving energy to the secondary as it is radiated away; the coupling is loose and the primary decrement is kept low. The rapid decrease of the oscillations in a quenched gap circuit is assisted by having a large ratio of capacity to inductance. This has the incidental advantage that the voltages across the condenser and coil are thus kept low.

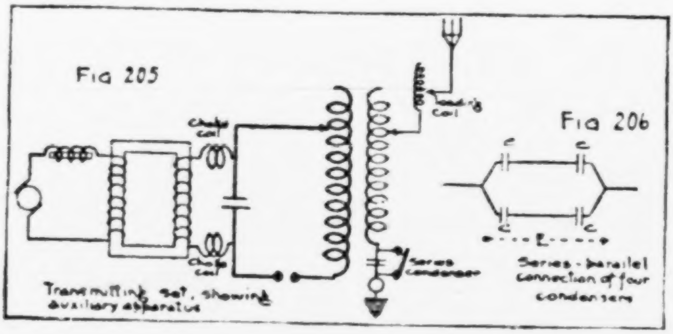
166. *Damping and Decrement.*—If the energy in the antenna circuit is dissipated at too rapid a rate, owing either to radiated waves or heat losses, the oscillations die out rapidly and not enough waves exist in a received train to set up oscillations of a well-defined period in a receiving antenna. Such waves are strongly damped and have a large decrement. They produce received currents of about the same value for a considerable range of wave lengths. Thus selective tuning is not possible.[2] To increase the number of waves sent out in each wave train from the open circuit (that is, to make the oscillations last longer) the resistance of the circuits must be kept low. When using a plain spark gap the coupling between closed and antenna circuits must be small enough not to take energy too fast from the closed [fol. 3492] oscillating circuits. At each condenser discharge the primary has a train of oscillations which at best die out long before another train starts (see Fig. 192); these oscillations are stopped more quickly, however, if the energy is drawn rapidly out of the circuit by the antenna. Close coupling is permissible only when a quenched gap is used (see remarks at the end of the preceding section). With any other kind of gap the secondary is kept oscillating by energy continually received from the primary.

A great many factors contribute to the resistance of the antenna circuit, and this must be kept as low as possible.

[2] See also section 116. The United States radio laws require that no station shall transmit a wave having a decrement exceeding 0.2.

The antenna must have a good low-resistance ground, must use wires of fairly low resistance, and must not be directly over trees or other poor dielectrics. The resistance of the closed circuit particularly must be very low. Heavier currents flow here than in the antenna wires. For this reason the closed circuit wires should be short and of large surface, preferably stranded wires or copper tubing. The condenser should be a good one, free from power loss.

167. *Additional Appliances.*—A number of additional appliances are necessary or desirable for the operation of a



damped wave generating set. The operation is improved by having a variable reactance (iron core inductor) in series with the alternator, to tune the alternator circuit to the alternator frequency. See Bureau of Standards Circular 74, p. 236.

Changes of Wave Length.—In many sets of apparatus it is customary to have connections arranged by means of which different chosen wave lengths, say 300 or 600 meters, can be transmitted without the necessity of a readjustment of the apparatus after each change. An antenna alone without any inductance coil has a natural wave length of its own, dependent upon its inductance and capacity. See Sections 116 and 145. The antenna is usually so designed that its natural wave length is shorter than the wave length to be used, and the wave length is brought up by adding inductance in series or merely by the added inductance of the secondary of the oscillation transformer. In the case of a small antenna, such as that on a small ship, it is necessary to use a large inductance. Since it is desirable to have the coupling loose, a part of the secondary inductance can be in a separate coil called the antenna "loading coil." This loading

[fol. 3493] coil is not coupled to the primary. Fig. 205 shows this arrangement. For a quick change of wave length a single switch is often provided, which, by a mechanism of levers, changes simultaneously the adjustments on all three coils. From these coils are taken out taps over which three switch blades pass, adjusting all the inductances to approximately the values needed for the particular wave length desired, keeping the circuits in resonance and at the proper coupling. For fine adjustments an additional variable inductor may be provided in the primary and in the secondary.

Fig. 205 also shows an arrangement whereby the operator can obtain wave lengths *shorter* than the natural wave length of the antenna by inserting a condenser in series (see Sec. 35) in the antenna circuit. In this case the loading coil will be set at zero turns to diminish the wave length. The condenser inserted must be capable of withstanding high voltages similar to those in the main transmitting condenser. By using a small capacity the wave length can be reduced to approach one-half of the natural wave length. It should not be reduced that much, however, for the radiation is inefficient if the condenser is too small. A zero capacity (an open circuit cutting off the antenna entirely from the ground) would be necessary to produce half wave length exactly.

Choke coils. Fig. 205 shows also choke coils to prevent the high frequency condenser discharge from getting into the transformer and puncturing the insulation. The coils choke down the radio frequency current but do not obstruct the low frequency charging current from the transformer. They must be specially designed so that they do not have capacity enough to allow the radio-frequency current to pass. They can often be dispensed with. See also Appendix 9, page 578.

168. *Adjustment of a Typical Set for Sharp Wave and Radiation.*—The set is assumed to be an inductively coupled set, arranged as in Fig. 205. The first step in adjusting it to work properly is to tune the closed circuit to the wave length which is to be used. This is usually done by varying the primary inductance, which includes the primary of the oscillation transformer. The primary capacity is usually fixed in value and not readily changed. Manufacturers usually mark on the primary variable inductance

the wave lengths corresponding to various settings. If this has not been done, it will be necessary to determine the wave length by the aid of a wavemeter having in its circuit a sensitive hot-wire ammeter. The wavemeter is placed at a distance of one or more meters from the coil of the closed circuit, and with the set in operation but the antenna circuit opened, the wavemeter coil is so turned that a small current is observed in the wavemeter ammeter. With the wavemeter set at the chosen wave length the closed circuit inductance is varied until resonance is obtained. If no resonance point is found, it is probable that the closed circuit inductance or capacity is either too large or too small. This inductance should be varied and a resonance point will be located after a few trials. It may also be necessary to increase or decrease the number of condensers used.

[fol. 3494] The next process is to adjust the secondary inductance and the coupling to obtain a pure sharp wave; that is, to get as much as possible of the power into the wave length that is to be used. Both primary and secondary circuits are closed and coupled together, using at first a fairly loose coupling unless the spark gap is a quenched gap. The secondary of the oscillation transformer or the antenna loading coil is varied until resonance is obtained, as shown by a maximum reading of the hot-wire ammeter in series with the antenna. This adjustment may be checked with a wavemeter. The wave length at which maximum current is obtained should be the same as the wave length for which the primary was adjusted. The wave meter should not be coupled to the secondary of the oscillation transformer, but to a loading coil or other coil at a distance, or to the ground connection. The coupling is then made closer until two points of resonance appear. It is desirable to have a pure wave; that is, have only one resonance point. Therefore the coupling is loosened until it is certain that there is just one sharp point of resonance. If the set has a quenched gap, the coupling is kept close, and varied only enough to insure a single, sharp, wave. The radiation or maximum current at the desired wave length will not occur when the coupling is tightest, nor will it necessarily occur when the reading of the antenna ammeter is greatest. The condition for efficient transmission is that maximum energy radiation should be secured at the wave length to which the set is adjusted.

It is next necessary to adjust the generator voltage and the length of the spark gap to get maximum current in the antenna at the desired wave length, and a good clear spark tone. The field current of the alternator and the length of the spark gap are adjusted until maximum current and best tone are obtained, the wave length and coupling adjustments being kept fixed. It is often desirable to vary the coupling a little and then repeat this adjustment, since in some cases a small increase of coupling may make it possible to obtain increased antenna current without seriously affecting the sharpness of the radiated wave. For a quenched gap, the coupling adjustment used for maximum antenna current and best tone is very critical.

The first two adjustments mentioned are made for the purpose of obtaining in the circuits resonance to the radio frequency which it is desired to radiate. It is, however, also important to obtain proper tuning with respect to the low audio frequency (perhaps 60 to 1,000 cycles) generated by the alternator. The audio frequency to which the circuit should be tuned to get the best *best* tone and most satisfactory operation is not the frequency supplied by the alternator, but is some 10 per cent to 20 per cent lower than the alternator frequency. The reactances of the transformer and of the rotor of the alternator are very important in determining the audio-frequency tuning characteristics, and for a given transmitting set the transformer and alternator are usually so designed that their reactances will be of the proper magnitudes at the operating fre- [fol. 3495] quency. If the transformer and alternator do not have the proper reactance, it may be necessary to supply an inductance in series with the alternator field. If such a series inductance is used, its setting to a proper value constitutes a fourth adjustment of a spark set. For a further discussion of tuning to the audio frequency, see Bureau of Standards Circular 74, p. 230, and H. E. Hallborg, Proceedings Institute Radio Engineers, vol. 3, p. 107, June, 1915.

DEFENDANT'S EXHIBIT G-5

Wireless Telegraphy, by Leggett, 1921

Author's Preface

It is a matter for comment that whilst numerous works have been published, and others are still being produced, dealing with the highly important science of Wireless Telegraphy, yet none of these give more than a mere outline of the Quenched-Spark System, a system which has been employed in almost every country throughout the world. In view of its extensive adoption in such countries as the United States of America, Australia, Japan, China, and Germany, and considering that it can for land stations claim to rank with the Marconi System in importance, this lack of literature in England is difficult to understand. It is, however, probably the result of national prejudice, since the system had its origin in Germany, where it was experimented with and established by the Telefunken Co. The history and development are given in detail in the Introductory Chapter, and the efficiency of the Quenched-Spark Gap is so undoubted that its scientific merits cannot be ignored or dismissed by appeals to false patriotism. The original Telefunken System has been developed to such a large extent in other countries, including England, that the Quenched-Spark System, which is its outcome, can now be viewed as an International System.

The Author hopes and believes that the present book fills a distinct gap in wireless literature, as there is no volume at present in English which deals in detail with the Quenched-Spark System, either as manufactured in this or in other countries; or of the original Telefunken System. Much of the apparatus has never previously been illustrated and described in the English language, and much, including very many illustrations, has never yet been published in any country. The Author is indebted to Messrs. Siemens Bros. & Co., Ltd., of Woolwich, for the majority of the photographs from which blocks have been made.

In the matter of block reproduction, at present a very expensive process, the Author wishes to give acknowledgment to the publishers, who have agreed with the writer that in technical descriptions a block is often of far more use than many pages of descriptive matter, and have, in

consequence, spared no expense in the preparation of illustrations.

The Author has had considerable experience of actual manufacture, installation and operation of nearly all the [fol. 3496] apparatus described, and he hopes, therefore; that serious technical errors will not be found in the present volume. In this endeavor to avoid errors the Author has been fortunate in obtaining the assistance of several experts in the reading of the proofs. He wishes to render thanks to Mr. H. Machen, A.M.I.E.E., Chief of the Wireless Department, Messrs. Siemens Bros. & Co., Ltd., Woolwich, for his careful revision of proofs and for many suggestions of improvement, and also for much valuable assistance during his career.

The Author would particularly pay acknowledgment to Mr. J. L. Bale, of Messrs. Chapman & Hall, who has throughout given much assistance to the Author in rendering into book form what was previously a set of technical notes taken over a period of several years.

For further general proof reading, and particularly for suggestions and information regarding aeronautical wireless, the Author wishes to express his sincere thanks to Mr. S. T. G. Andrews, B.Sc. (Engineering). His gratitude is also due to Dr. L. Isserlis, B.A., Mathematical Tripos, and Mr. S. G. Starling, B.Sc., A.R.C.S., Examiner in Physics, London University, who have been kind enough to read the proofs of Chapter II. and offer suggestions.

The chapter on wireless propagation embodies an analogy which the Author has himself found very useful in interpreting wireless phenomena. Whilst not offered as an actual explanation, possibly open to criticism, it should not detract from the more practical portions of the book.

The chapter upon maintenance has been included in order to render the book of greater use to operators of the Quenched Spark System, who are rapidly increasing in number now that a number of well-known shipping lines are fitting many of their new vessels with this system.

Acknowledgment is also due to the "English Mechanic" for permission to reproduce much of the matter of the earlier chapters, which the Author originally wrote for this Journal.

In conclusion, the Author would state that whilst in agreement with the spirit of the extract from the "Elec-

trician" (given on p. vi), he does not himself believe the actual position to be as bad as this extract would imply, but the apparent general backwardness in English wireless may be partly attributed to the mistaken policy of Government Departments in withholding much scientific information obtained during the late War at great expense to the country. A particular example is afforded by the Signals Experimental Establishment Pamphlets which are available to those able to use the Library of the Institution of Electrical Engineers, and doubtless to many commercial firms having foreign connections, but which cannot be purchased by the general public who have borne the expense of their production. In this connection the Author believes Prof. Townsend of Oxford undertook for the military authorities extensive scientific researches showing comparisons between Open-, Quenched-, and Rotary-Spark Gaps. No details of these tests of efficiency, which would un-[fol. 3497] doubtedly be of great assistance to shipowners and others requiring to install new wireless apparatus, have yet been published.

Bernard Leggett.

London, November, 1920.

In Fleming's treatise the achievements of Mr. Marconi and the apparatus of the Marconi Company are dealt with at great length, but it is a matter for comment that the apparatus of this company's greatest competitor, namely, the Telefunken and Quenched-Spark system, receives very scanty notice, and indeed its name does not appear in the index to his book.

Eccles' book is far more general in nature, but as the book is much more restricted in size, his matter on the Telefunken and Quenched-Spark systems is necessarily small.

The sources of information regarding the original Telefunken system are very restricted, especially to those unable to read German. Such restriction of information is purely insular. The average English reader is practically unaware of the existence of any important commercial system of wireless telegraphy other than that of the Marconi Company, and is quite astounded when told of the existence of another system which, outside England and a few of its Colonies, is perhaps for land stations the most extensively adopted by other countries.

Since the original home of the Quenched-Spark system is Germany, national prejudice has, until recently, prevented the full recognition of this important system of wireless telegraphy, in spite of its great scientific merits.

There is, however, only one test of any scientific apparatus, namely, its efficiency. Since the Quenched-Spark Gap has at least twice the efficiency of any other form of spark gap, it is far from patriotic to neglect the possibilities of this system. On the contrary, it is a truer form of patriotism to examine, impartially and scientifically, the merits and demerits of foreign scientific work, German or otherwise, and then to utilise the results of such examination to the furtherance of British science and technology.

* * * * * * *

As evidence that the only true test of any scientific apparatus depends upon actual results, the author might mention the following incident described by an English paper, "The China Coast Shipping Gazette," as long ago as 3rd November, 1911.

The English steamer "Brodmore" was in Hankow harbour in distress with a perishable cargo of meat. The skipper, owing to destruction of the land lines by insurgents, was unable to wire to Shanghai for a relief ship to salve his cargo. He approached the British Consul, with a request that a British warship in harbour should be utilised to send a wireless message to Shanghai and was informed that the wireless range of this warship was insufficient for it to do so. Lying in the harbour was the German warship "Leipsig" fitted with Telefunken apparatus. As it was in permanent communication with the German warship "Nurnberg" in Shanghai, the captain of the "Leipsig" [fol. 3498] offered to assist the "Brodmore" skipper by sending his message, the cargo so being eventually salved.

The above mentioned paper quoted upon the incident to the following effect: "The system upon which the English Navy depends shows itself in a very bad light, and the English ships are unable to bridge large distances, while the German warships fitted with the Telefunken system are in easy permanent direct communication between Hankow and Shanghai. The German warship 'Leipsig' in Hankow, is, we hear, in permanent communication with the 'Nurnberg' in this harbour, and exchanges regular

* * * * * * *

This shows us that, with coupled circuits, which of necessity to avoid radiation of energy upon many wavelengths, we are compelled to adopt, *we obtain in the aerial two oscillations of very different wavelengths having maxima λ_1 and λ_2.*

Since, at any instant, a receiving station can only be tuned to one wavelength (the largest λ_2), *the energy of the other*

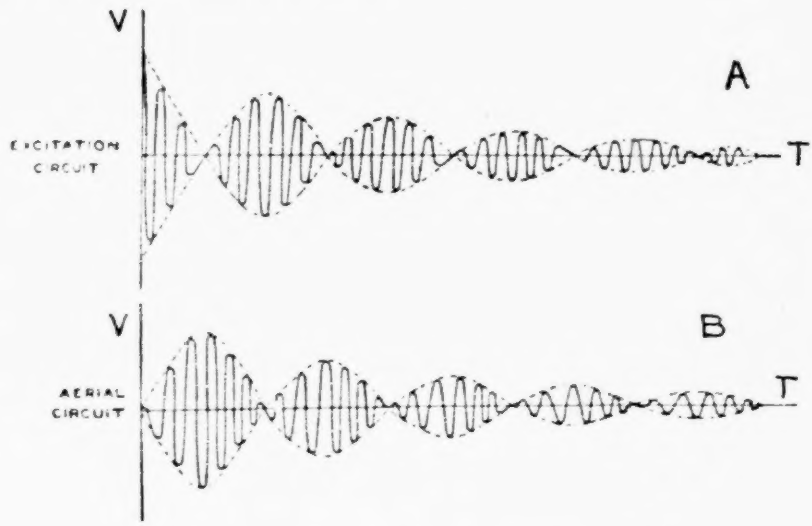


FIG. 13.—Oscillations in open-spark transmitter (Wien).

maximum wavelength λ_1 represented by the shaded area (since energy is proportional to the square of the current) and which is large in proportion to the energy of λ_2, *is totally wasted* and only gives rise to "jamming," or interference, at other neighbouring receiving stations.

The Necessity of Quenching

On pages 46 and 47 we showed by mathematical analysis the existence of two oscillations in a secondary or aerial circuit, since we obtained two different periods of oscillation.

From consideration of resonance, on page 53, we obtained a value for the secondary voltage, which was seen to have two components, each of which represented a distinct oscillation. We also found that the total current in the aerial [fol. 3499] had two components, which explained the double peak of the resonance curve, obtained in practice for coupled circuits.

The actual presence of this dual oscillation can be actually shown by use of the Braun cathode tube.

If this is done we obtain curves for the variation of voltage in the two circuits as follows:

Those familiar with the theory of sound will at once recognize that the aerial and excitation circuits both oscillate with "beats". There are, in each circuit, two oscillations of different periods and damping, which as they agree or differ in phase give rise to electrical "beats" similar to beats obtained with mechanical systems vibrating to produce sound.

Since the energies of the oscillations in each circuit sometimes assist and sometimes oppose each other, we must always have a loss of energy in the latter case.

The forced oscillation in the aerial is produced by the further transfer of energy from the excitation circuit, and, as the latter is an alternating source of current, for short periods we will have the forcing voltage equal zero.

This will allow energy to surge back from the aerial circuit, since the voltage of the latter, owing to the free oscillation, is not zero, and the spark gap will be bridged, so causing a great loss of energy owing to its high resistance, which dissipates the electrical energy as heat and light energy.

Further advance of time permits the oscillations produced in the excitation circuit to again excite the aerial, this cycle continuing until all the energy is dissipated either by radiation from the aerial or by resistance losses at the spark gap.

If we can now discover some means whereby immediately the excitation circuit has first imparted its energy to the aerial circuit, the resistance of the spark gap of the former circuit is made so great that energy surging back into it is unable to bridge the spark gap, all the energy connected magnetically and statically with the two circuits will (neglecting the very small resistance of the aerial circuit) only have one means of dissipation, namely, by useful radiation from the aerial circuit. Since the forced oscillation of the excitation circuit ceases to exist, *all the energy will be radiated on one wavelength, namely, the natural wavelength of the aerial circuit.*

The act of stopping the flow of energy in the excitation circuit is known as "quenching," since it is brought about by preventing or quenching the return spark. Also since all the energy is transferred from the excitation to the

aerial circuit after the passage of a single spark, the aerial circuit is said to be "impact" of "shock excited".

Quenching is best brought about by use of a special form of spark gap described in detail in the next section.

The effects of quenching are very noticeable in practice. [fol. 3500] Considering first the variations of voltage in the two circuits, these are shown as follows:

It will be noticed the oscillations of the excitation circuit are practically non-existent, and that the train of oscillations of the aerial has a very low logarithmic decrement, and therefore a long persistence. Beats do not occur, and there is therefore no waste of energy in beat production.

The aerial oscillations tend therefore to continuous oscillations and the area of the curve they produce, being proportional to voltage (or current), determines the energy. The great increase in aerial energy will be at once recognised, when compared to the oscillation of the aerial when the return sparking is not quenched and beats occur.

Consider now the effect of quenching on the resonance curve.

Curves for oscillations produced by open and Quenched-Spark gaps are given on pp. 334 and 335 of Fleming's "Principles of Electric Wave Telegraphy" from actual experiments by Fleming and Dyke.

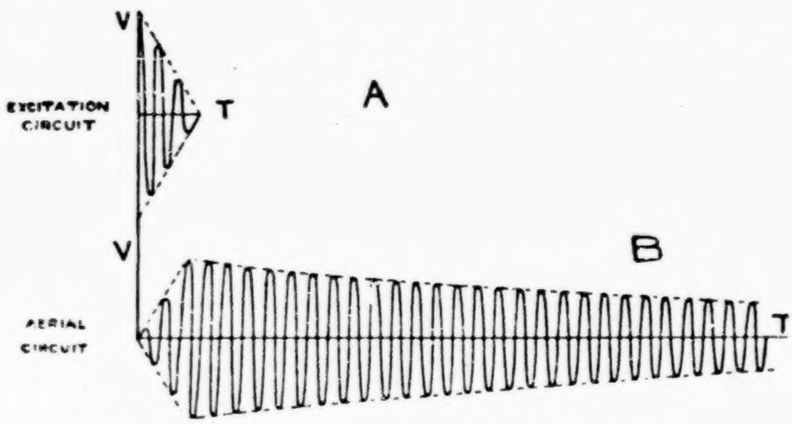


FIG. 14.—Oscillations in quench-spark transmitter (Wien)

As, however, unless one recognises the differences in coupling in the original curves, the whole difference between open and quenched gaps is apt to be overlooked, the author has taken the liberty of redrawing them in a series of curves

(Fig. 15), each of which show the open and quenched-gap curves for the same particular degrees of coupling.

In the case of the open-gap curves when quenching does not occur, the curve will be found to have two distinct peaks of very different wavelength and low current value, which is proportional to the energy radiated.

For a coupling of 26 per cent., with the quenched gap there is only one sharply defined peak (the other having

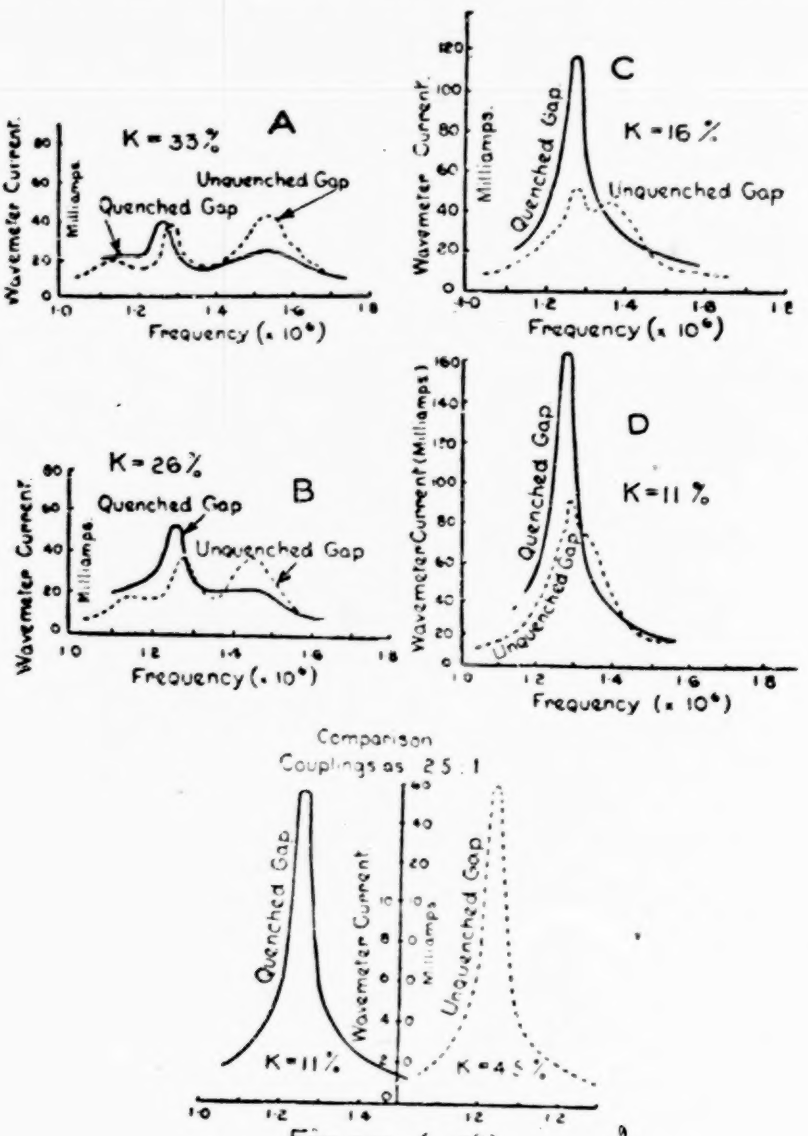


Fig. 15.—Resonance curves for coupled circuits (Fleming, redrawn).

nearly disappeared at a coupling of 26 per cent.). Compared with the open-spark curve of similar coupling, its current value is much greater, and therefore more energy is radiated upon a sharply defined wavelength.

In the case of the double peaked open-gap curves, a receiving station can only resonate to one wave length, and [fol. 3501] therefore the energy of the other is totally wasted and only serves to cause interference to other stations.

The last curves of this series show the difference of coupling necessary to obtain the same current effect with open and quenched gaps. These couplings are, according to Fleming, 11 per cent. for the quenched gap as opposed to a much weaker coupling of 4.5 per cent. for the open gap. This means that the coupling must be weakened and therefore a less transference of energy from excitation and aerial circuit takes place, and to render the aerial currents equal [fols. 3502-3505] much greater energy in the prime circuit must be present. According to Fleming's figures it would be presumably necessary to use $\frac{11}{4.5} = 2.5$ times the prime energy to obtain the same aerial energy, i. e., with the quenched gap the efficiency is about 75 per cent. if we take the usual value of 25 per cent. for the open gap, a figure for the quenched gap which *which* has been quenched by its opponents.

DEFENDANT'S EXHIBIT N-5

MAUBORGNE'S Sketches-

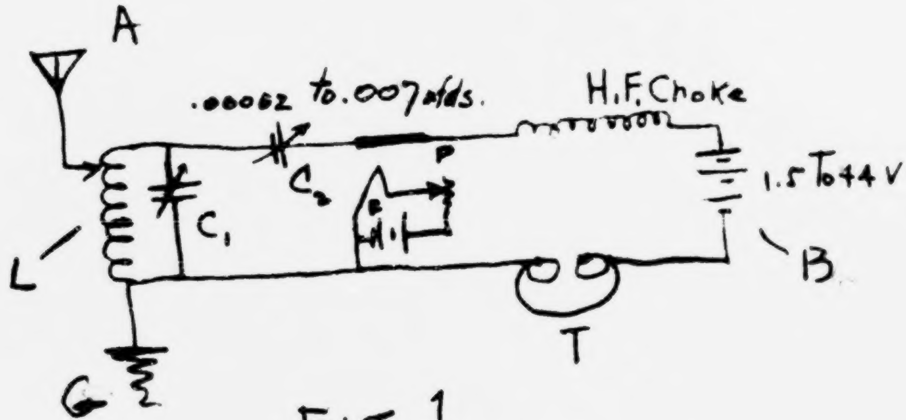


Fig. 1

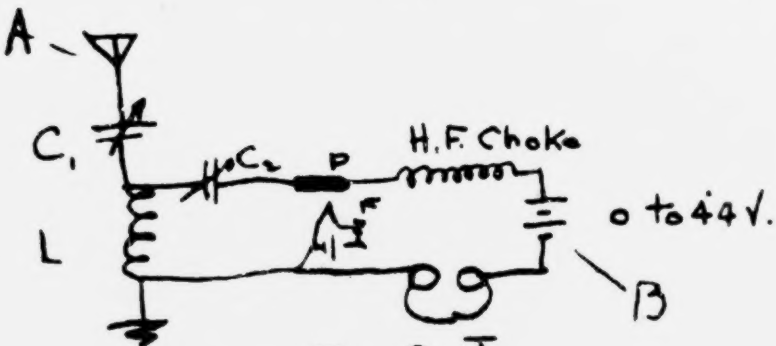
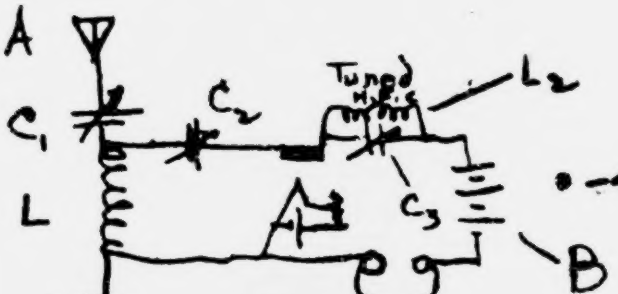


Fig. 2



J.O. Mauborgne

FIG. 3

MAUBORGNE's Sketches

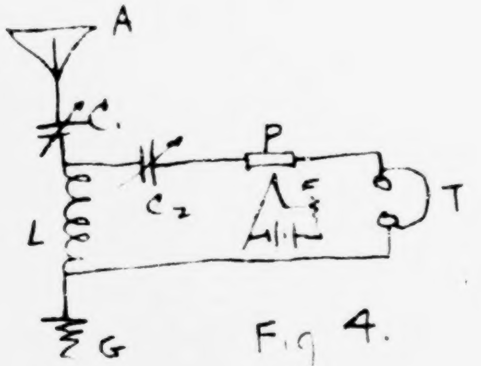


Fig. 4.

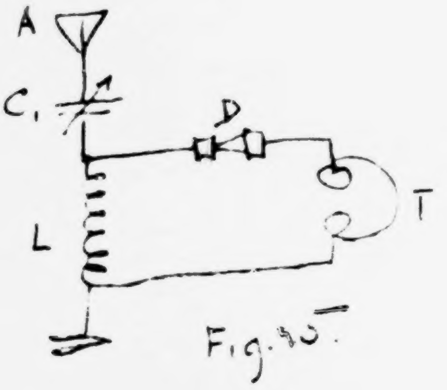


Fig. 5

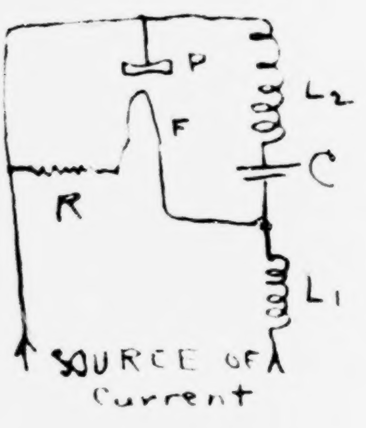


Fig. 6.

J O Mauborgne

MAUBORGNE'S Sketches

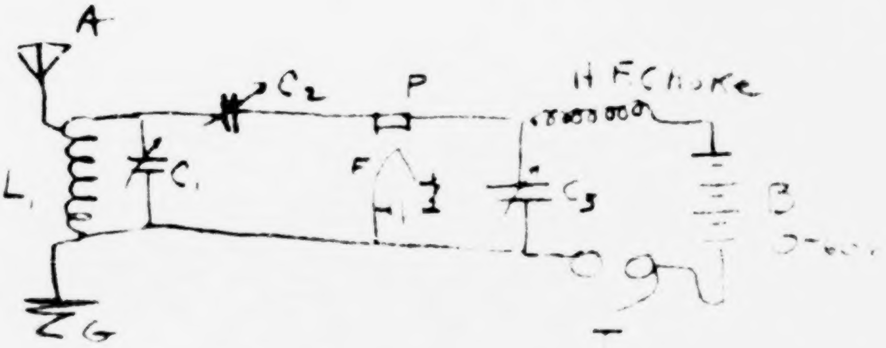


Fig 7

Fig 8.

544

GVVP10A

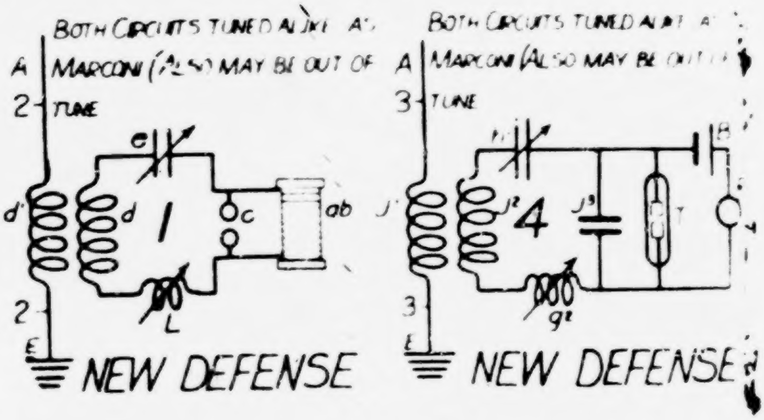
PICKARD CHART

STONE 4-CIRCUIT TUNING PATENT

714,756 FILED PRIOR TO MARCONI'S FILING AND GRANTED PRIOR TO MARCONI'S

NEW DEFENSE AS TO VALIDITY & NON-INFRINGEMENT

~~IN PENDING BROOKLYN TRIAL AGAINST ATLANTIC CO~~



TRANSMITTER FIG 5 RECEIVER FIG 6

ALMOST IDENTICAL WITH FIG'S 1 & 2 OF MARCONI PAT IN SUIT

~~NEVER BEFORE USED IN TRIAL AGAINST MARCONI PAT~~

~~SAVE IN UNCOMPLETED TRIAL IN ATLANTIC COMMUNICATION CO~~

U. S. COURT OF CLAIMS
MARCONI WIRELESS TELEGRAPH CO. OF AMERICA, Plaintiff.
v.
THE UNITED STATES, Defendant.

No. 33,642.
DEFENDANT'S EXHIBIT G-8
Pickard Chart - Stone 4-circuit tuning patent.

Notary Public.

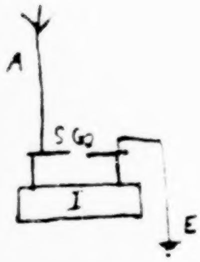


Fig 1

Plain Antenna Transmitter
A = Antenna
SG = Spark Gap
E = Earth
I = Induction Coil

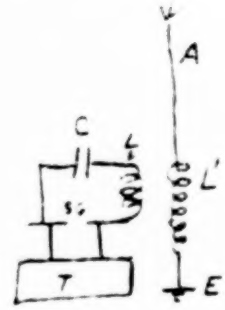


Fig 2

Tuned Coupled Circuit Transmitter
A = Antenna
L' = " Coupling and [illegible]
E = Earth
C = Condenser
L = Primary [illegible]
SG = Spark Gap
T = Trans[illegible] or Ind[illegible] Coil

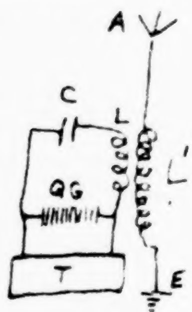


Fig 3

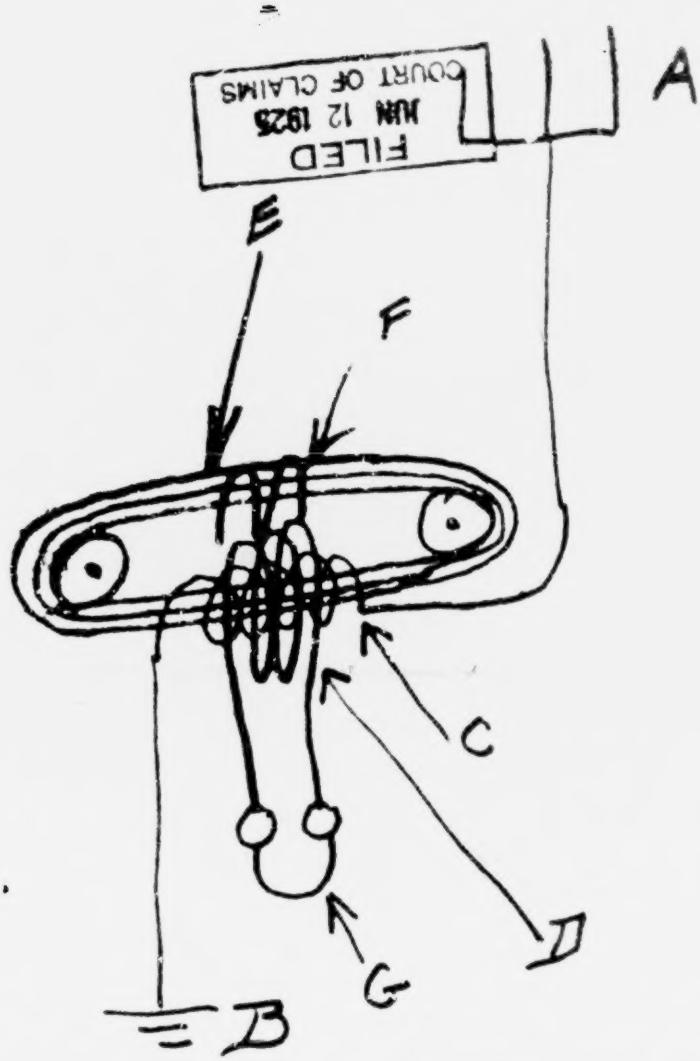
IN THE COURT OF CLAIMS OF
THE UNITED STATES.
MARCONI WIRELESS TELEGRAPH COM-
PANY OF AMERICA,
vs.
THE UNITED STATES.
No. 33,642.

DEFENDANT'S EXHIBIT Q-5.
Marriott Sketch.

Notary Public

Impulse Excitation Trans[illegible]

A = Antenna
L' = " [illegible] inductance
E = Earth
C = Condenser
L = Primary inductance
CG = Quenched Gap
T = Trans[illegible] or induct[illegible]

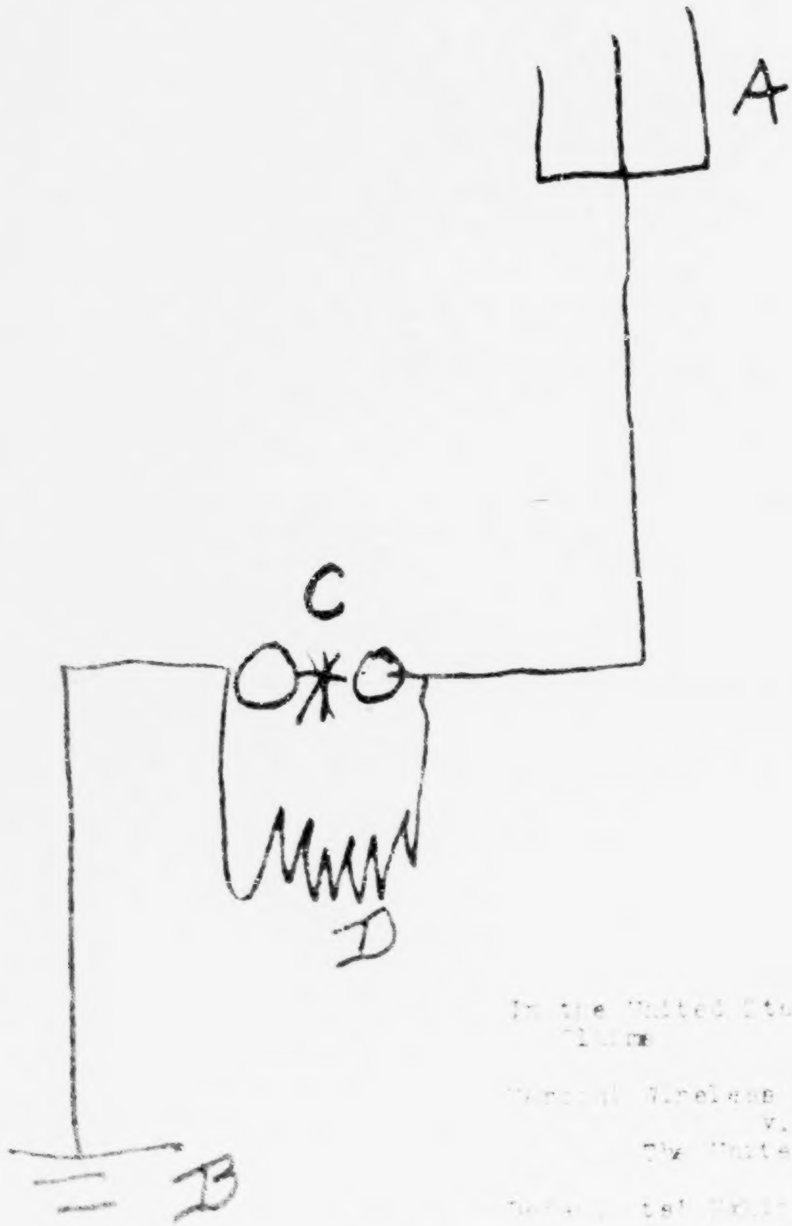


In the United States Court of Claims

Marconi Wireless Telegraph Company
v.
The United States

Defendants' Exhibit S-5
Sarnis Sketch

3948



In the United States Court of Claims

Marconi Wireless Telegraph Company
v.
The United States

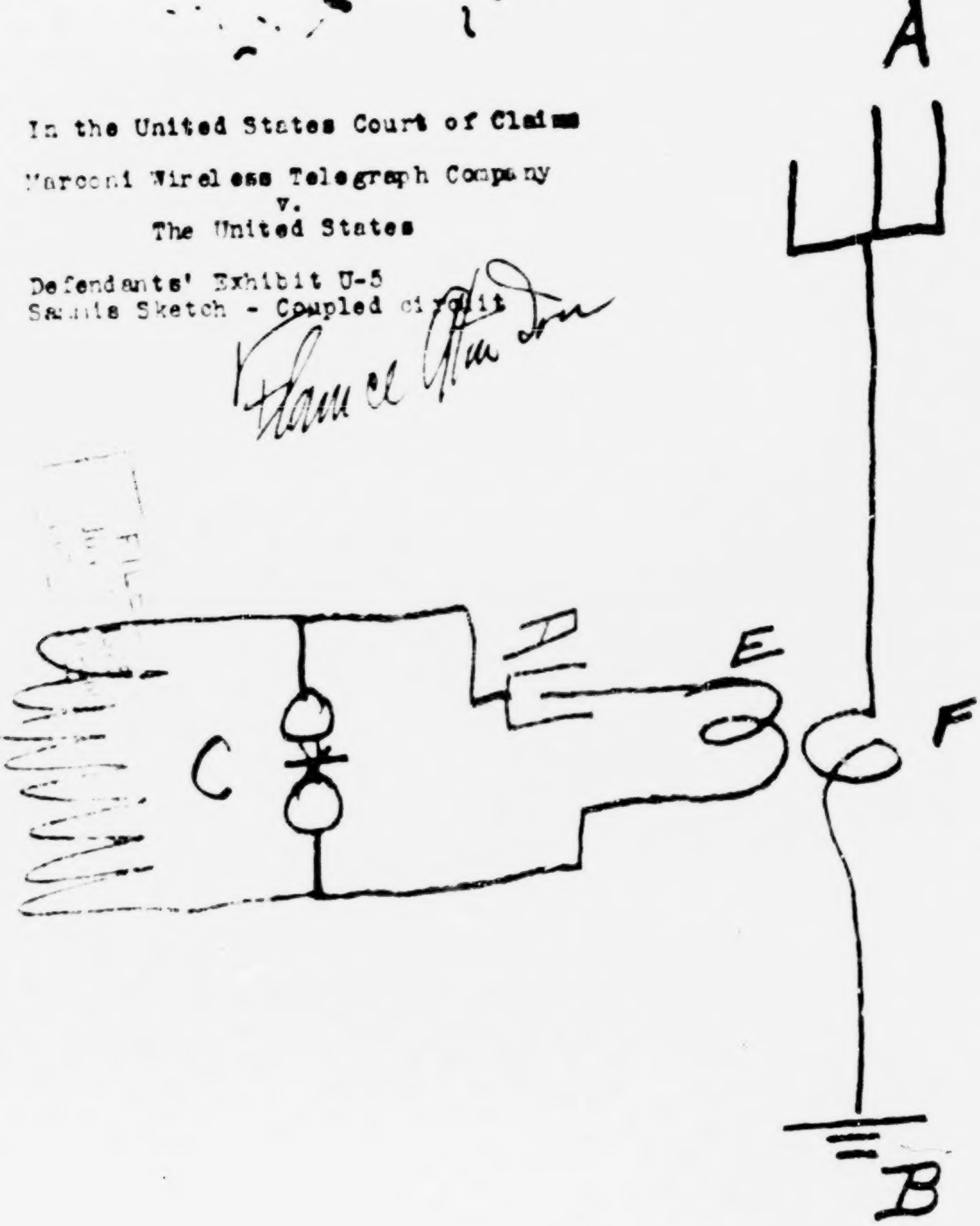
[illegible] Exhibit [illegible]
[illegible]

U-5

In the United States Court of Claims

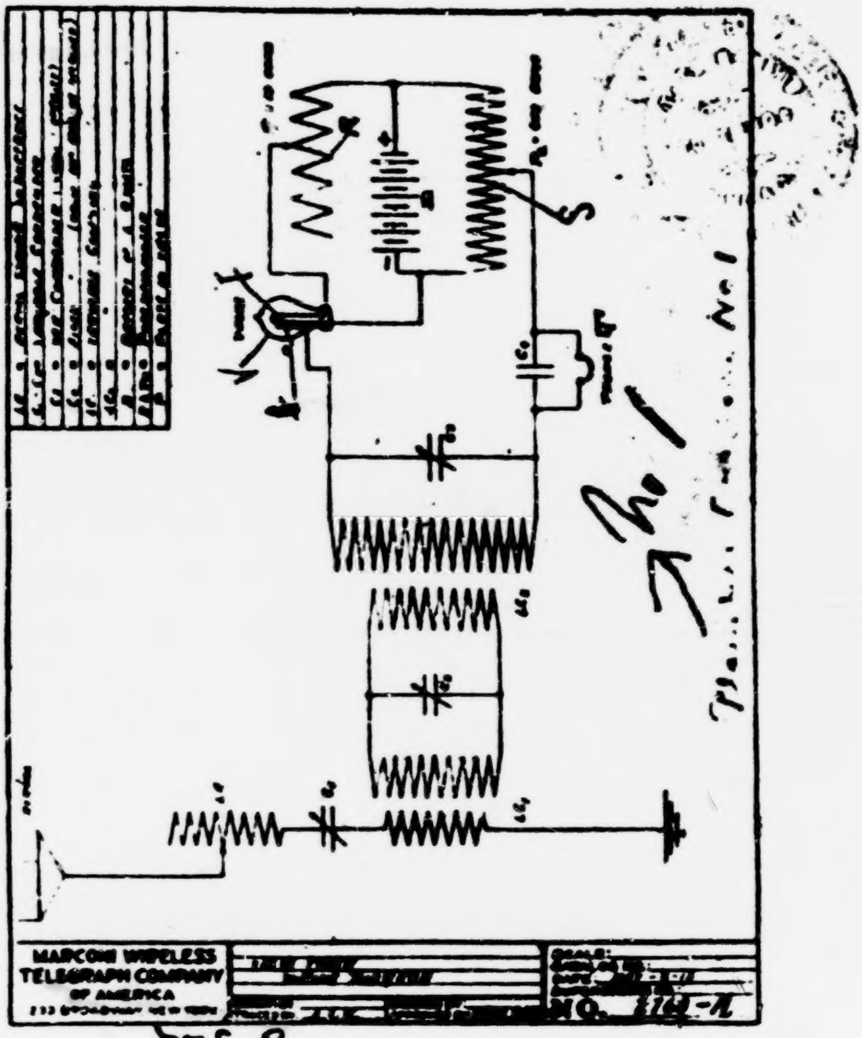
Marconi Wireless Telegraph Company
v.
The United States

Defendants' Exhibit U-5
Sammis Sketch - Coupled circuit

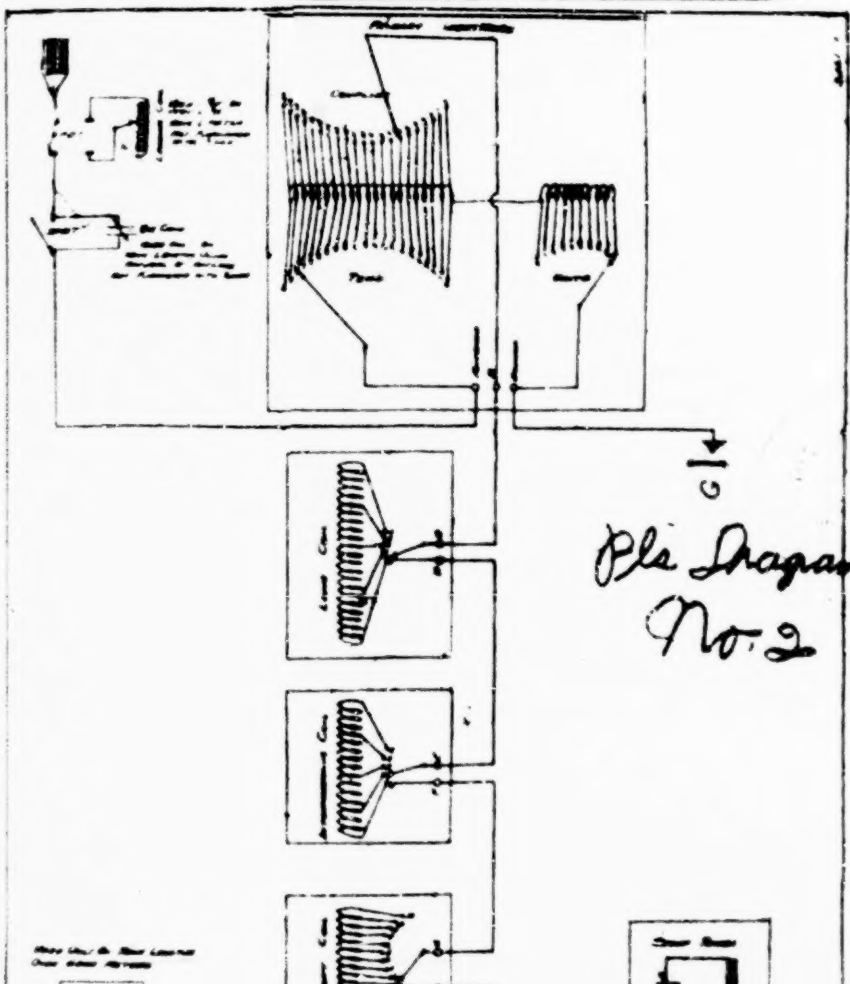


V-5

Defendant's Exhibit V-5



DEFENDANT'S EXHIBIT W-5



[fol. 3516] 2—390

DEFENDANT'S EXHIBIT X-5

United States of America, Department of the Interior, United States Patent Office

To all to whom these presents shall come, Greeting:

This Is To Certify that the annexed is a true copy from the Records of this Office of the File Wrapper, Contents and Drawing in the matter of the Letters Patent of Guglielmo Marconi, Assignor to Marconi's Wireless Telegraph Company, Limited, Number 763,772, Granted June 28, 1904, for Improvement in Apparatus for Wireless Telegraphy.

In Testimony Whereof I have hereunto set my hand and caused the seal of the Patent Office to be affixed at the City of Washington, this 14th day of May, in the year of our Lord one thousand nine hundred and fourteen and of the Independence of the United States of America the one hundred and thirty-eighth.

[Seal Patent Office, United States of America.]

J. T. NEWTON,
Acting Commissioner of Patents.

(Here follows 1 photolithograph, side folio 3517)

2-437

3954A

ABANDONED Revived Feb. 29, 1904
NUMBER (SERIES OF 1900).

36,010

1900
~~ABANDONED~~
DIV. 16

DIV. 16
(EX'R'S BOOK). 82-5

PATENT No. 763,772

Name Guglielmo Marconi

Assor to Marconi's Wireless Telegraph Company, Limited, of same place, (their)

of London

County of

~~State~~ of England

Invention

Apparatus for Wireless Telegraphy

Division of App. No. , filed , 190

PARTS OF APPLICATION FILED.	ORIGINAL.		RENEWED.
Petition	Nov 10	, 1900	, 190
Affidavit	" "	, 1900	, 190
Specification	" "	, 1900	, 190
Drawing	" "	, 1900	, 190
Model or Specimen none		, 190	, 190
First Fee Cash $15 Nov 10		, 1900	, 190
" " Cert.		, 190	, 190
Appl. filed complete	NOV 10	, 1900	, 190

Examined L H Campbell June 1 , 1904 , 190
Countersigned J . Babson , 190

For Commissioner. For Commissioner.

Notice of Allowance June 1 1904 , 190

Final Fee Cash $20 June 9 , 1904 , 190

" " Cert , 190 , 190

Patented June 28 , 1904

Associate Attorney Geo. E. Robertson
605 - 7th St
Washington
D. C.

Attorney Betts, Betts, Sheffield & Betts
120 Broadway
N. Y.

Name
Patent No.

Serial Number
Date of Patent

3517

[fol. 3518] Amount Received $15. Chief Clerk, CK.

To the Commissioner of Patents:

Your Petitioner, Guglielmo Marconi, a Subject of the King of Italy, residing at 18 Finch Lane, Threadneedle Street, in the City of London, England, Electrician, which is his postal address, prays that Letters Patent may be granted to him for the "Improvements in apparatus for "wireless telegraphy," set forth in the annexed specification: and he hereby appoints Frederic H. Betts, Samuel R. Betts, James R. Sheffield *and* Louis F. H. Betts, constituting The Firm of Betts, Betts, Sheffield & Betts, of 120 Broadway, in The City, County and State of New York, United States of America, his attorneys, with full power of substitution and revocation, to prosecute this application, to make alterations and amendments therein, to receive the Patent and to transact all business in the Patent Office connected therewith.

GUGLIELMO MARCONI.

U. S. Revenue Stamp, 25 Cents. W. H. B. Nov. 9, 1900.

[fol. 3519] Cancelled per Sub Spec.

To all whom it may concern:

Be it known that I, Guglielmo Marconi, a Subject of the King of Italy, residing at 18 Finch Lane, Threadneedle Street, in the City of London, England, Electrician, have invented certain new and useful "Improvements in apparatus for wireless telegraphy," of which the following is a Specification:—

The object of this invention is not only to increase the efficiency of the apparatus hitherto employed, but also to so control the action as to cause intelligible communications to be established with one or more stations only out of a group of several receiving stations.

[fol. 3520] In the specification of a former patent No. 586193 a transmitter is described which consists of an induction coil, one terminal of the secondary

circuit being connected to a metal sphere connected to earth and the other to a similar sphere connected to an insulated conductor which generally takes the form of a more or less vertical wire which may or may not terminate or have attached to it a metal body of extended surface, giving it increased electrical capacity.

According to the present invention the vertical wire is connected to earth through the secondary winding of a transformer of a kind suitable for the transformation of very rapidly alternating electric currents and the primary of this transformer is connected to the spheres or terminals of the sparking appliance.

A condenser of suitable capacity is introduced in series with the primary or each end of the primary may be connected to one of the plates of two condensers of suitable capacity, the other plates of which are connected to the sparking appliance.

This device enables much more energy to be imparted to the radiator than heretofore the approximately closed circuit of the primary being a good conserver and the open circuit of the secondary a good radiator of wave energy.

The arrangement works as follows:—

On pressing the key and actuating the induction coil (in order to produce a signal) the condenser in circuit with the transformer is charged and subsequently discharges through the spark gap. If the capacity, the inductance, and the resistance of [fol. 3521] the circuit are of suitable values, the discharge is oscillatory, with the result that alternating currents of high frequency pass through the primary of the transformer, and induce similar oscillations in its secondary these oscillations being communicated to the elevated conductor.

The circuit of the elevated conductor should be suitably attuned for this purpose.

The effect of these oscillations in the elevated conductor is to inductively affect similar distant conductors if the self induction

and capacity of the said conductors is of a suitable value or values.

At the receiving end a receiver is employed capable of being actuated by electrical oscillations of high frequency such as are described in the specifications Nos. 627,650; 647,007; 647,008; 647009 and 586,193.

The four circuits namely those including the primary and the secondary of the transformer in the transmitter and the primary and the secondary of the transformer in the receiver should be so adjusted as to make the product of the self induction multiplied by the capacity the same in each case that is to say their electrical time period should be the same but they may also be octaves of each other.

In employing this invention to localise the transmission of intelligence to one out of several receiving stations the time period of the circuits at each of these stations is so arranged as to be different from those of the other stations. If the time period of the circuits of the [fol. 3522] transmitting station are varied until they are in resonance with those of one of the receiving stations that one alone out of all the number of receiving stations will respond, provided that the distance between the transmitter and receiver is not too small.

The adjustment of the self induction and capacity of the circuits can be made in any convenient manner those which are preferred being set out in the following description.

Figures 1 and 2 are diagrams of the transmitter and of the receiver respectively, whilst Figure 3 shows a side view and Figure 4 an edge view of a transformer used at the transmitting station and Figures 5 to 8 show various induction coils used at the receiving station.

a is a battery, b a Morse key, c a Ruhmkorff coil the primary of which is in circuit with the battery whilst the terminals of the secondary are connected to the primary d of a transformer one of the connections being through a condenser e, or there may be a condenser in both of the connections. The secondary d' of the transformer is connected to an aerial conductor A which may have at its top a metallic cylinder f and to earth or a capacity E. Between the secondary and the aerial conductor or it might be between the secondary and earth is sometimes inserted an inductance coil g having numerous coils and the connection is such that a greater or less number of [fol. 3523] turns of the coil can be put in circuit, the proper number to use being ascertained by experiment.

The receiver (Figure 2) consists of an aerial conductor A which may have a cylinder f' at its top connected through an inductance coil g' similar to g and through the primary j' of an induction coil to earth or a capacity E; a small condenser h may be inserted in parallel with the primary j'.

Cancelled Per Sub Spec.

The secondary j^2 of the induction coil is divided in the middle and has its inner ends connected to the plates of a condenser j^3 while its outer ends are connected it may be through inductance coils g^2 similar to g to a detector or coherer T; a condenser h' may be inserted in parallel with the detector. The local circuit containing a battery cell B and relay or telegraph instrument R is connected through choking coils c' c^2 to the plates j^3 of the condenser.

The condensers h h' are preferably in the form of two metallic tubes separated by a dielectric and sliding telescopically on

each other as in this way their capacity can readily be varied with accuracy to tune the circuits.

The following are details of arrangements which have been fornd to work well.

The cable used for the aerial conductor at either station and for the transformer d d' at the transmitting station is in all the examples given composed of seven strands [fol. 3524] of copper wire .889 mm. in diameter. The aerial conductor at the receiving station is in each instance exactly similar to that at the transmitting station for the corresponding tune.

The details of the transformers d d' are as follows:

Transformer No. 1. The total length of the primary d is .946 metres and it is bent round a square d^2 of insulating material of which the side is .3048 metres long while the secondary d' consists of two turns or squares one lying on each side of the primary (see Figures 3 and 4). The insulation of both primary and secondary consists of 1.25 mm. of rubber and 1 mm. of jute making a total thickness of 2.25 mm.

Transformer No. 2 is exactly similar to No. 1 except that the total length of the primary d is 1.93 metres.

Transformer No. 3. The primary consists of ten turns of cable wound on a cylindrical core 10.16 cm. in diameter; over this but separated from it by 2 mm. of paper or other insulating material is wound the secondary also of ten turns.

The inductance coils g g' are of copper wire 6.25 mm. in diameter wound on a cylinder 10.64 cm. in diameter an interval of 2.28 mm. being left between adjacent turns while the inductance coils g^2 inserted in series with the secondary j^2 of the induction coil at the receiving station are

of copperwire, silk covered, of .19 mm. [fol. 3525] diameter wound on cylinders 3.7 cm. in diameter.

Figures 5 to 8 show details of the induction coils j^1 j^2.

These diagrams are greatly enlarged half longitudinal sections, but are not strictly to scale. In place also of showing the section of each coil or layer of wire as a longitudinal row of dots or small circles as it would actually appear, it is for simplicity shown as a continuous longitudinal straight line.

Induction coil No. 1—see Figure 5. The primary consists of 3.048 metres of silk covered copper wire .71 mm. in diameter wound in one layer on a core 2.9 cm. in diameter. Insulating material is wound over and on each side of this so as to make a cylindrical core 3.13 cm. in diameter on which is wound the secondary each half consisting of 6.4 metres of silk covered copper wire .19 mm. in diameter joined to 13.41 metres of silk covered copper wire .37 mm. in diameter wound in the same sense as the primary, the thinner wire being over the primary and the thicker being beyond the ends of the primary.

Induction coil No. 2—see Figure 6. The primary j^1 wound on a core 1.6 cm. in diameter consists of 100 turns of copper wire .037 cm. in diameter insulated with single silk and coated with paraffin wax. the secondary j^2 is of copper wire [fol. 3525½] .019 cm. in diameter insulated with single silk covering and is wound over the primary commencing in the middle and in the same sense as the primary. Each half of the secondary is in layers of the following number of turns: first layer 77, second 49, third 46, fourth 43, fifth 40,

sixth 37, seventh 34, eighth 31, ninth 28, tenth 25, eleventh 22, twelfth 19, thirteenth 16, fourteenth 13, fifteenth 10, sixteenth 7, seventeenth 3, making 500 in all.

Cancelled Per Sub Spec.

Induction coil No. 3—see Figure 7. The primary consists of 3.048 metres silk covered copper wire .19 mm. in diameter and the secondary 30.48 metres long of silk covered copper wire .1 mm. in diameter wound in one layer on a core 4 cm. in diameter, the primary being in one layer outside the secondary.

Induction coil No. 4—see Figure 8. The primary consists of 3.048 metres silk covered copper wire .37 mm. in diameter wound on a core 2.9 cm. in diameter and inserted in a tube j^x of 4 cm. external diameter on which is wound the secondary of 27.432 metres silk covered copper wire .12 mm. in diameter, the break at the middle of the secondary being over the middle of the primary.

The following tables give the adjustments, those details opposite any tune in the transmitting station table being of course used in connection with those opposite the same tune in the receiving station table.

[Matter enclosed between rules erased in copy.]

(Here follows 1 photolithograph, vide folio 3526)

Transmitting Station.

Tune	Aerial Conductor	Transformer d d'	Inductance Number of turns of g included	Capacity in microfarads e	Length of spark in millimetres
No. 1	36.576 metres of cable	No. 1	None	.006934	3
No. 2	ditto	No. 1	45	.016395	4
No. 3	ditto	No. 2	None	.004112	3
No. 4	ditto	No. 2	100	.016849	4
No. 5	Zinc cylinder 9.144 metres long, 1.524 metres in diameter hoisted 3.048 metres above ground	No. 2	None	.001600	12.5
No. 6	30.48 metres of cable	No. 3	None	.000573	4

[fol. 3527]

Receiving Station

Tune	Induction coil	Capacity in microfarads of Inductance h	h'	g' Number of turns	introduced in g^2
No. 1	No. 1	omitted	omitted	none	none
No. 2	No. 1	omitted	00004	45	none
No 3	No. 2	0046	omitted	up to 21 may be inserted	none
No. 4	No. 2	0046	omitted	100	2 coils of 15.24 metres at each end of secondary
No. 5	No. 3	omitted	omitted	none	none
No. 6	No. 4	omitted	omitted	none	none

It will be observed that both the transmitter and the receiver are the same for tunes 1 and 2, and that when the capacity of the condenser e is varied, the two stations can be brought into tune by including 45 turns of each of the coils g g' and by introducing a condenser h' of small capacity [fol. 3528] in parallel with the coherer T. Similarly the transformer and receiver are the same for tunes 3 and 4 and when the capacity of e is varied, the stations are tuned by including 100 turns of each of the coils g g' and also by including the two coils g^2.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed I declare that what I claim is:

Cancelled per Sub. Spec.

1 A transmitter for electric wave telegraphy consisting of a spark producer having its terminals connected through a condenser with one circuit of a transformer the other circuit being connected to a conductor and to a capacity.

2. In a transmitter for electric wave telegraphy the combination of a transformer one circuit of which is a persistent oscillator and the other a good radiator and means for setting up oscillations in the oscillator.

3. A transmitter for electric wave telegraphy consisting of a spark producer having its terminals connected through a condenser with one circuit of a transformer the other circuit being connected to a conductor and to earth the time

period of electrical oscillations in the two circuits being the same or octaves of each other.

4. In a transmitter for electric wave telegraphy, the combination of a transformer one circuit of which is a persistent oscillator and the other a good radiator the time period of electrical oscillations in the two circuits being the same or octaves of each other and means for setting up oscillations in the oscillator.

5. A system of electric wave telegraphy in which both the transmitter and the receiver contain a transformer the time period of electrical oscillations in the four circuits of the two transformers being the same or octaves of each other.

[fol. 3529] 6. A system of electrical wave telegraphy in which both the transmitter and the receiver contain a transformer one circuit of which is a persistent oscillator and the other a good radiator or absorber of electrical oscillations all four circuits having the same time period or being octaves of each other.

Cancelled per Sub. Spec.

7. In a transmitter for electric wave telegraphy, the combination of a pair of terminals, means for producing sparks between the terminals, a transformer, connections between one winding of the transformer and the terminals, a condenser in one of the connections, a conductor, a capacity and connections between the other winding of the transformer and the conductor and capacity.

[Matter enclosed between rules erased in copy.]

Guglielmo Marconi.

Witnesses: R. B. Ransford, G. F. Warren.

[fol. 3530] Great Britain,

England.

London, ss:

Guglielmo Marconi, the above named Petitioner, being duly sworn deposes and says that he is a Subject of the King of Italy, and resident of 18 Finch Lane, Threadneedle Street, in the City of London, England, Electrician, and that he verily believes himself to be the original, first and sole inventor of the "Improvements in apparatus

for wireless telegraphy", described and claimed in the annexed specification; that he does not know and does not believe that the same was ever known or used before his invention or discovery thereof; or patented or described in any printed publication in any country before his invention or discovery thereof; or more than two years prior to this application; or in public use or on sale in the United States for more than two years prior to this application; and that no application for patent on said improvement has been filed by him or his representatives or assigns in any country, except as follows: in Great Britain dated 26th April 1900.

Guglielmo Marconi.

Sworn to and subscribed before me this twenty sixth day of October 1900. G. F. Warren, Notary Public. (Seal.)

U. S. Revenue Stamp, 10 Cents. W. H. B. Nov. 9, 1900. (Foreign Revenue Stamps.)

[fol. 3531] 2—260.

Div. —, Room 91.

Address only "The Commissioner of Patents, Washington, D. C.," and not any official by name.

Paper No. —.

All communications respecting this application should give the serial number, date of filing, title of invention, and name of the applicant.

Department of the Interior, United States Patent Office.

Washington, D. C., Dec. 24, 1900.
Mailed Dec. 24, 1900.

Guglielmo Marconi,
Care, Betts, Betts, Sheffield & Betts,
120 Broadway, New York, N. Y.

Please find below a communication from the Examiner in charge of your application filed Nov. 10, 1900, Ser. No. 36,010, for Apparatus for Wireless Telegraphy.

C. H. DUELL,
[THOMAS EWING],*
Commissioner of Patents.

[*Words and figures enclosed in brackets erased in copy.]

Claim 1 is rejected upon the patent to Lodge, 29,505 of 1897, Telegraphy, Circuits and Systems, particular reference being had to figure 7. This patent describes a system of syntonic telegraphy on the induction system. To use the coil *e* as the primary of the transmitting circuit, as shown in the patent to Marconi, 586,193, July 13, 1897, Circuits and Systems, is deemed unpatentable, especially in view of the fact that in said patent statement is made that tuned circuits may be used.

As to claims 2, 4 and 6, it is required that further and clearer description be inserted in the specification as to what is meant by "persistent oscillator" and "good radiator". Until such requirement is complied with it must be held that there is insufficient basis in the specification to warrant said claims.

Claim 3 is rejected upon the British patent to Lodge, 29,505, of 1897, cited above. To have two associated tuned circuits in inductive relation to each other is deemed unpatentable; see the patent to Pupin, 640,515, Jan. 2, 1900, Circuits and Systems.

Claim 5 is also rejected upon the patent to Lodge cited above. To use step up transformers with the arrangement shown in figure 7 and step down transformers all of which are tuned, is thought to be comprehended by the disclosure of said patent.

[fol. 3532] Claim 7 is rejected upon the patent to Lodge cited above. To use such transmitting device associated with Marconi's transmitting device as disclosed in his pat-

3

ent No. 586,19[5]*, cited above, is deemed unpatentable.

C. C. DEAN,

Examiner, Div. 16.

C. D. E.

[fol. 3533] U. S. Patent Office.

In the Matter of the Application of GUGLIELMO MARCONI, for Patent for Apparatus for Wireless Telegraphy. Filed November 10, 1900. Serial No. 36,010.

July 1st.
New York, [March]* ^ 1901.

Hon. Commissioner of Patents,
Washington, D. C.

SIR:

In the above-entitled matter, we authorize and request the cancellation of the Specification and Claims on file down to, but not including, the signatures, and the substitution of the following:

Specification.

To all whom it may concern:

Be it known that I, Guglielmo Marconi, a subject of the King of Italy, residing and having a Post-Office address at 18 Finch Lane, Threadneedle Street, in the City of London, England, Electrician, have invented certain new and useful Improvements in Apparatus for Wireless Telegraphy, of which the following is a Specification:

My invention relates to apparatus for communicating electrical signals, without wires, and by means of Hertz
or electric waves
Per F. oscillations ^ , and the object of the invention is to increase the efficiency of the system, and to provide new and simple means whereby oscilla-
or electric waves
Per F. tions ^ from a transmitting-station may be lo-
one
Per F. calized, when desired, at any ^ selected receiving-
Per F. station or stations [only]* out of a group of [fol. 3534] several receiving-stations.
(Reissue No. 11,913, dated June 4, 1901)

In my prior United States Patent No. 586,193, ^ I have shown and described the combination, at a transmitting station, of an oscillation-producer, such an induction-coil

[*Words and figures enclosed in brackets erased in copy.]

having one end of its secondary-coil connected to one contact of a spark-producer, and to the earth, and having the other end of the said secondary connected to the opposite contact of the spark producer and to a vertical wire or elevated plate; and I have further shown, as a receiving-station an imperfect contact connected in circuit with a vertical receiving-wire and with the earth.

According to the present invention, the system includes, at the transmitting-station, the combination, with an oscillation-transformer, of a kind suitable for the transformation of very rapidly alternating currents, of a persistent oscillator and a good radiator, one coil of said transformer being connected between the aerial wire, or plate, and the connection thereof to earth, while the other coil of the transformer is connected in circuit with a condenser, a spark producer Insert F′

Per F. and an induction-coil, (constituting the persistent oscillator) controlled by a signalling instrument; the complete system also includes at a receiving-station, an oscillation-transformer, one coil whereof is included between the aerial receiving wire and earth, constituting a good absorber of electrical oscillations, while

Per F. a device responsive to electric waves, such as an imperfect contact, or a device for operating the same, is included in a circuit with the other coil of said transformer.

The system also requires as essential elements thereof, the inclusion in the lines (at both stations) from the aerial conductor to the earth, of variable inductances and the use at both stations of means for varying or adjusting the inductance of the two circuits, at each station to accord with each other. By this arrangement of apparatus, I am able [fol. 3535] to secure a perfect "tuning" of the apparatus at a transmitting-station and at one or more of a number of receiving stations.

Referring to the accompanying drawings: Fig. 1 indicates, diagrammatically, the arrangement of apparatus at a transmitting-station; Fig. 2 indicates, diagrammatically, the arrangement of apparatus at a receiving station; Figs. 3 and 4 are views, plan and side, of the preferred form of transformer at the transmitting-station; Figs. 5, 6, 7 and 8, are

diagrammatic views of forms of transformers at the receiving station.

The transmitting-station is provided, under my present
invention with a source *a*, of current, electri-
F. E. R. an induction
June 8, 1904 cally connected in circuit with the primary of ^
Per F. [a Ruhmkorff]* coil *c*, and with a circuit-closing key, *b*; or otherwise controlled by a signalling-instrument. In the secondary-circuit of said induction-coil, the spherical terminals, or other contacts, of a spark-
electric wave or
Per F. producer, or other ^ oscillation-producer, are included, with a shunt therefrom, in which shunt is included the primary-coil, *d*, of an oscillation-transformer, such as d^2. A condenser, *e*,—preferably one provided with two telescoping metallic tubes separated by a diaelectric, and arranged to readily vary the capacity, by being slid upon each other— is included in one connection from
induction
Per F. the ^ [Ruhmkorff]* coil to the transformer-winding, *d*.

Cancelled Per C.
A similar, or other, condenser may be included in the return connection between said parts.

The secondary-coil, *d'*, of the transformer, is connected—at one end—to the earth, E, and at its other end
Insert Y^2 to a vertical wire, A, or an elevate plate*d*, *f* ^.
Y^2

The illustrated arrangement of parts, at a transmitting-station, enables much more energy to be imparted to the [fol. 3536] radiator, *f*, the approximately-closed circuit of the primary being a good conserver, and the open circuit of the secondary being a good radiator of wave-energy. My experiments have demonstrated that the best results are obtained, at the transmitting-station, when I use a persistent-oscillator- an electrical circuit of su h a character that, if electromotive force is suddenly applied to it, and the cur-

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[*Words and figures enclosed in brackets erased in copy.]

rent then cut off, electrical oscillations are set up, in the circuit, which persist, or are maintained, for a long time in the primary-circuit, and use a good radiator (i. e., an electrical circuit which very quickly imparts the energy of electrical oscillations to the surrounding ether, in the form of waves) in the secondary circuit.

In operation, the signalling-key, k, is pressed, and this
induction
Per F. closes the primary of the ^ [Ruhmkorff]* coil. Current then rushes through the transformer-circuit, and the condenser c is charged and subsequently discharges through the spark-gap. If the capacity, the inductance, and the resistance of the circuit are of suitable values, the discharge is oscillatory, with the result that alternating currents of high frequency pass through the primary of the transformer and induce similar oscillations in the secondary, these oscillations being rapidly radiated
in the form of electric waves
Per Y. ^ by the elevated conductor.

For the best results, and in order to effect the selection of the station or stations whereat the transmitted oscillations are to be localized, I include, in the open secondary-circuit, of the transformer—and preferably between [fol. 3537] the radiator, f, and the secondary-coil, d',—an inductance-coil (g, Fig. 1), having numerous coils, and the connection is such that a greater or less number of turns of the coil can be put in use, the proper number being ascertained by experiment.

At the receiving-stations employing my present invention, I prefer to use a receiver such as those described in my several United States Patents, Nos. 586,193; 627,650; 647,007; 647,008; 647,009 and 668,315—capable of being
waves or
Per Y. effected by electrical ^ oscillations of high-frequency.

Insert Y³.>

Referring to Fig. 2, f' indicates a plate or cylinder, not essential at either transmitter or receiver, at the upper end of an elevated conductor A, which is connected to the primary-coil j', of a transformer or induction-coil, and thence to earth, E. In a shunt, around said primary, j', I usually place a condenser, h, preferably similar, in construction and operation, to the condenser, c. An inductance-coil, g', of

variable inductance, is interposed in the primary-circuit of the transformer, being preferably located between the cylinder, f′, and the coil j′, and the inductance of said coil may be adjusted, in accordance with the method described by me in my [pending Application, Serial No. ——, filed February 21st., 1901, for]* Letters Patent of the United States, No. 676,332,

Per C. ^ to harmonize with the inductance of coil, g, at the transmitting-station Fig. 1 of the accompanying drawing) or with that of the coil or coils at one or more of the transmitting-stations included in the communicating-system.

[fol. 3538] The secondary-coil, j^2, of the transformer is wound in two parts, [especially]* ^ preferably as described in my United States Letters Patent, No. 668,315, dated February 19th, 1901, and the outer ends of said coil are connected in certain cases, through one or more interposed inductance-coils, g^2,—preferably of variable inductance—with the terminals of a coherer, T, or other detecter of electrical oscillations. The inner ends of the split secondary-coil are connected to the plates of a condenser, j^3. A condenser, h^1, is some^e times included in a shunt around the detecter. T. B. is a battery, and R a relay, connected to the condenser j^3, and controlling a telegraphing-instrument or a printing-device. c' and c^2 are choking-coils, preventing oscillations, from the secondary, j^2, running into the battery circuit, and

Per F. thereby confining them to the ^ wave responsive device [detecter]*.

Substitute F⁴

The four circuits—i. e., the primary and secondary circuits at the transmitting-station and the primary and secondary circuits at any one of the receiving-stations, in the communicating-system—are to be so adjusted as to make the product of the self-induction, multiplied by the capacity, the same in each case, that is to say, their electrical time period shall be the same, or octaves of each other.

[Matter enclosed between rules erased in copy.]

[*Words and figures enclosed in brackets erased in copy.]

In employing this invention to localize the transmission of intelligence at one of several receiving-stations, the time period of the circuits at each of the receiving stations is so arranged as to be different from those of the other stations. If the time-periods of the circuits [of the]* of the trans-
[fol. 3539] mitting-station are varied until they are in resonance with those of one of the receiving-stations, that one alone of all of the receiving-stations will respond, provided that the distance between the transmitting and receiving stations is not too small.

The adjustment of the self-induction and capacity of any or all of the four
Per F. [the]* circuits can be made in any convenient manner, and employing various arrangements of apparatus, those shown and described herein being preferred.

In practice, I have found the following preferred details of arrangements of apparatus to work well:

The aerial conductors A, at all stations, and the conductor for the transformer-windings at the receiving-stations, are
Per C. composed of seven strands of copper wire, .889 m m in diameter. The transformer at the transmitting station may be of any of the following forms:

(1) Around a block or core, d^2, preferably a square block (say .17 meters wide) of insulating material is wound [on]* a primary-coil, d, in length .946 metres, while the secondary, d', consists of two turns, or squares, one lying on each side of the primary (see Figs. 3 and 4). The insulation of both primary and secondary consists of 1.25 m m of rubber, and 1 m m of jute, making a total thickness of 2.25 m m.

(2) A transformer, in all essentail respects similar to (1), but with a primary of 1.93
Insert B'. metres B'

(3) A transformer having a cylindrical core 10.16 c m. in diameter, and with a primary having ten turns wound thereon; over this, but separated by 2 m.m. of paper—or
[fol. 3540] other insulant—the secondary, also of ten turns.

[Insert A.]* Insert D'.

The inductance-coils, g and g', are, preferably, of copper wire, 6.25 m. m. in diameter, wound on a cylinder 10.64 c. m.

in diameter, with an interval of 2.28 m. m. between adjacent turns. The inductance-coils g^2, at the receiving station, are, preferably, of silk-covered copper wire, .19 m. m. diameter, wound upon cylinders 3.7 C. m. in diameter.

Various forms of induction-coils j', j^2, may be used. Figs. 5, 6, 7 and 8, show details of different forms.

The Figures show, diagrammatically, greatly enlarged longitudinal sections, not strictly to scale. Instead of showing the section of each coil or layer of wire as a longitudinal row of dots, or small circles, as it would actually appear, it is, for simplicity, shown as a continuous longitudinal straight line.

j'
Per C. Referring to Fig. 5, the primary, [J']* ^, preferably consists of 3.046 metres of silk-covered
and
" " copper-wire, say, ^ 71 m. m. in diameter, wound
of ebonite or other insulating material
" " in one layer on a core ^ 2.9 c. m. in diameter. Insulating material is wound over and on each side of this, so as to make a cylindrical core, say 3.13 c. m. in diameter, on which is wound the secondary, each half of which consists of 6. 4 meters of silk-covered copper-wire .19 m. m. in diameter, joined to 13.41 metres of silk-covered copper-wire, .37 m. m. in diameter, wound in the same
sense
[wire]* ^ as the primary, the thinner wire being over the primary and the thicker being beyond the ends thereof.

[fol. 3541] The form of induction-coil shown in Fig. 6, has a primary of one hundred turns of copper wire .037 c. m. in diameter, wound on a core, j, (2.9 c. m. in diameter), with a single silk-covering and coated with paraffin wax; the secondary j^2, is of copper wire, .019 in diameter insulated with a single silk covering, and is wound over the primary, commencing in the middle and in the same way as the primary. Each half of the secondary is in layers of the following number of turns:—first layer, 77 turns; second layer, 49 turns; third layer, 46 turns; fourth layer, 43 turns; fifth layer, 40 turns; sixth layer, 37 turns; seventh layer, 34 turns; eighth layer 31 turns; ninth layer, 28 turns; tenth layer, 25 turns; eleventh layer, 22 turns; twelfth layer, 19 turns, thirteenth layer, 16 turns; fourteenth layer, 13 turns; fifteenth layer, 10 turns; sixteenth layer, 7 turns; and seventeenth layer, 3 turns—making 500 turns in all.

A third form of induction-coil—shown in Fig. 7—has a primary of 3.048 metres of silk-covered copper-wire, .19 m. m. in diameter, and a secondary of 30.48 metres of silk-covered copper wire, .1 m. m. in diameter, wound in one layer on a core 4 c. m. in diameter, the primary being in one layer outside of the secondary.

The fourth form of induction-coil is shown in Fig. 8. Its primary consists of 3.048 metres of silk-covered copper wire, .37 m. m. in diameter, would on a core 2.9 c. m. in diameter, and inserted in a tube, j^x, of 4 c. m. external diameter, on which is wound the secondary of 27.432 metres of silk covered copper wire, .12 m. m. in diameter, the break at the middle of the secondary being over the middle of the primary.

Cancelled [Insert A².]* Insert C'.>

/ [fol. 3542] The following tables give preferred adjustments, those details opposite any tune in the transmitting station table being, of course, used in connection with those opposite the same tune in the receiving-station table.

Transmitting Station

Tune	Aerial Conductor	Transformer d, d'	Inductance Number of Turns of g included	Capacity microfarads	Length of spark in millimetres
No. 1	36.576 metres of cable	No. 1	None	.006934	3
No. 2	do.	No. 1	45	.016395	4
No. 3	do.	No. 2	None	.004112	3
No. 4	do.	No. 2	100	.016849	4
No. 5	Zinc cylinder, 9.144 metres long, 1.524 metres in diameter, and hoisted 3.048 metres above ground	No. 2	None	.001600	12.5
No. 6	30.48 metres of cable.	No. 3	None	.000573	4
No. 7	four vertical wires each 48.6 metres long connected together at	No. 4	None	.016	6

	top and bottom but kept apart throughout their length by being suspended from the arms of a wooden cross each arm of which is 4 metres long				
[fol. 3543] No. 8	One vertical wire 48 metres long	No. 5	None	.007	6
No. 9	One vertical wire 30.4 metres long	No. 6	None	.0026	5

Receiving Station

Tune	Induction Coil	Capacity in microfarads of h	h'	Inductance introduced in g' Number of turns	g^2
No. 1	No. 1	omitted	omitted	none	none
No. 2	No. 1	omitted	.00004	45	none
No. 3	No. 2	.0046	omitted	up to 21 may be inserted	none
No. 4	No. 2a	.0046	omitted	100	2 coils of 15.24 metres at each end of secondary
No. 5	No. 3	omitted	omitted	None	none
No. 6	No. 4	omitted	omitted	None	none
No. 7	No. 5	omitted	omitted	none	none
No. 8	No. 6	omitted	omitted	none	none
No. 9	No. 7	omitted	omitted	none	none

It will be observed that both the transmitter and the receiver are the same for tunes 1 and 2, and that when the capacity of the condenser, *e*, is varied, the two stations can be brought into tune by including forty-five turns of each of the coils *g*, *g'*, and by introducing a condenser, *h'*, of small capacity, in parallel with the coherer, T. Similarly, the transmitter and receiver are the same for tunes 3 and 4, and when the capacity of *e* is varied, the stations are

[fol. 3544] tuned by including one hundred turns of each of the coils g and g', and by also including the coils g^2.

While I have herein shown and described details of construction and of arrangement found by me to be useful, yet I do not wish to be understood as confining my Claims thereto; obviously modifications, which are within my invention, will readily suggest themselves to skilled persons.

What I claim is:

Sub. B[2]

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1. A system of electric wave telegraphy, in which both the transmitter and the receiver contain a two-circuit oscillation-transformer, the time period of electrical oscillations in the four circuits of the two transformers being the same or harmonics of each other, substantially as described.

2. A system of electric wave telegraphy, in which both the transmitter and the receiver contain a two-circuit oscillation-transformer, one circuit of which is a persistent oscillator and the other a good radiator or absorber of electrical oscillations, substantially as described.

3. A system of electric wave telegraphy in which both the transmitter and the receiver contain a two-circuit oscillation-transformer, one circuit of which is a persistent oscillator and the other is a good radiator or absorber of electrical oscillations, all four circuits having the same time period or being harmonics of each other, substantially as described.

[Matter enclosed between rules erased in copy.]

Cancelled per C

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4. In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a transmitting station, of an induction-coil; an electric circuit containing [a]* ^the^ secondary of said coil, a condenser and the [fol. 3545] primary coil of the oscillation-transformer; a sparking-device electrically connected with the secondary of the induction-coil; and the secondary-coil of the oscillation transformer electrically connected through a variable inductance, at one end, to capacity which may be the earth

[*Words and figures enclosed in brackets erased in copy.]

and, at the other end, to an [insulated]* aerial conductor; substantially as and for the purpose described.

[Matter enclosed between rules erased in copy.]

Insert C².>

11 [9 5].* In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a transmitting-station, of an induction-coil; an electric circuit containing the secondary of said coil, a condenser and the primary-coil of the oscillation-transformer; a producer of electric waves of high frequency

Per F. ^ [sparking-device]* electrically connected with the secondary of the induction-coil; a signalling instrument in circuit with the primary of the induction coil; the secondary-coil of the oscillation-transformer electrically connected, at one end to capacity [which may be

Per D. the earth]* and, at the other end, to an inductance, and an aerial conductor connected to the inductance, substantially as and for the purpose described.

12 [10 6].* In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a transmitting-station, of an induction-coil; an electric circuit containing the secondary of the said coil, a condenser and the primary-coil of the oscillation-transformer; producer of electric waves of high frequency

Per F. a ^ [sparking-device]* connected with the secondary of the induction coil; a signalling-instrument in circuit with the primary of the induction-coil; the secondary-coil of the oscillation-transformer electrically connected, at one end, to capacity [which may be the earth],* and, at the other end, to a variable inductance, and an aerial conductor connected to the variable inductance, substantially as and for the purpose described.

[fol. 3546] Cancelled per C

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7. In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a trans-

[*Words and figures enclosed in brackets erased in copy.]

mitting-station, of an induction-coil, an electric circuit, containing a persistent oscillator, and the secondary of the induction-coil and the primary of the oscillation-transformer; means for setting up oscillations in the oscillator; and an open-circuit, constituting a good radiator, and containing the secondary of the oscillation-transformer; substantially as and for the purpose described.

[Matter enclosed between rules erased in copy.]

[Sub. B³].* Cancelled

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8. In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a transmitting-station, of an electrical circuit, containing the primary of the oscillation-transformer and a persistent oscillator; a signalling-instrument controlling the oscil-ator; and an open circuit, constituting a good radiator, and containing the secondary of the oscillation-transformer and a variable inductance; substantially as and for the purpose described.

[Matter enclosed between rules erased in copy.]

Sub. D³

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11 [9].* At a station employed in wireless telegraphy, the combination, with an oscillation-transformer, of an open circuit comprising an [insulated]* aerial conductor connected with one end of a coil of the transformer; a connection from the other end of the said coil to capacity which may be the earth; a variable inductance included in said open circuit; and electrical connections from the other coil of the oscillation,-transformer to an oscillation-producer or
affected
Per B. to means ^ [effected]* by electrical oscillations; substantially as and for the purpose described.

[Matter enclosed between rules erased in copy.]

[*Words and figures enclosed in brackets erased in copy.]

Cancelled per D

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12 [10].* At a station employed in wireless telegraphy, the combination, with an oscillation-transformer, of an [fol. 3547] open-circuit comprising an [insulated]* aerial conductor connected with a variable inductance; a connection from said inductance to one end of a coil of the transformer; a connection from the other end of said coil to capacity which may be the earth; and electrical connections from the other coil of the oscillation-transformer to an
affected
Per B. oscillation-producer or to means [effected]* by electrical oscillations; substantially as and for the purpose described.

[Matter enclosed between rules erased in copy.]

[Sub. B⁴].* Cancelled

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11. At a station employed in wireless telegraphy, the combination, with an oscillation-transformer, of an open-circuit comprising an [insulated]* aerial conductor connected with a variable inductance; a connection from said inductance to one coil of the transformer; a connection from the other end of said coil to capacity which may be the earth; a shunt around said coil and containing a condenser; and electrical connections from the other coil of the oscillation-transformer to an oscillation-producer or to means effected by electrical oscillations, substantially as and for the purpose described.

[Matter enclosed between rules erased in copy.]

Cancelled per D

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13 [12].* In a system of wireless telegraphy, the combination at a receiving station, of an oscillation-transformer, an open circuit comprising, in part, an aerial conductor connected with one end of the primary coil of the oscillation-transformer; a connection from the
Per C. other end of the said coil to capacity [which may be the earth]:* a variable inductance in said open circuit; electrical connections from the secondary coil of the oscillation-transformer to means affected by re-

ceived electrical-oscillations; and a variable inductance included in the last named electrical connection; substantially as and for the purpose described.

[fol. 3548] Cancelled Per D

14 [13]*. In a system of wireless telegraphy, the combination, at a receiving station, of an oscillation-transformer, an open circuit comprising, in part, an aerial conductor connected with one end of the primary-coil of the oscillation-transformer; a connection from the other end of said coil to capacity which may be the earth: an inductance in said open circuit; electrical connections from the secondary-coil of the oscillation-transformer to means affected by received electrical-oscillations, an inductance included in the last-named electrical connections, and means for adjusting the inductance of one or both circuits, so as to accord with each other, substantially as and for the purpose described.

[Matter enclosed between rules erased in copy.]

19 [15 14]*. In a system of wireless telegraphy, the combination at a receiving-station, of an oscillation-transformer: an open circuit comprising, in part, an aerial conductor connected with one end of the primary-coil of the oscillation-transformer; a connection from the other end of

may

Per C. said coil to capacity [which might ^ be the earth:]* a variable inductance in said open circuit; and electrical connections from the secondary- coil of the oscillation-transformer to a receiving-instrument.

wave responsive

Per F. battery, condenser, ^ [imperfect-contact]* device and a variable inductance, substantially as and for the purpose described.

Sub D'

16 [15]*. In apparatus for communicating electrical signals, a transmitting-station having an oscillation-transformer, an open radiating circuit comprising an aerial con-

ductor connected to one end of the secondary-coil of the oscillation-transformer, a connection from the other end of said coil to capacity [which may be the

Per C. earth]*, a variable inductance in said circuit, and a persistent oscillator electrically connected

[fol. 3549] in circuit with the primary-coil of the oscillation-transformer; a distant receiving-station having a oscillation-transformer, an open receiving-circuit, thereat containing an aerial conductor connected to one end of the primary-coil of the oscillation-transformer, a connection from the other end of said coil to capacity which may be the earth, a variable inductance in said circuit, and electrical connections from the secondary-coil of said oscillation-transformer to means affected by received electrical oscillations, substantially as and for the purpose described.

[Matter enclosed between rules erased in copy.]

Cancelled Per C

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16. In a system of electric wave telegraphy, the combination

Per B. [employment]*, both at a transmitting-station and at a receiving-station, of two circuits, inductively associated with one another each of these circuits possessing capacity and inductance, and one being nearly constituting

Per B. closed except for a spark-gap, and [therefore]* a persistent oscillator, and the other circuit associated with it syntonically being an open circuit constituting or

" " cuit, and [therefore]* a good radiator [of] absorber of electric-wave energy, substantially as and for the purpose described.

[Matter enclosed between rules erased in copy.]

[Sub B⁵]* Cancelled

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17. In a system of electric-wave telegraphy, the employment, at a transmitting-station, of a closed circuit compris-

ing a persistent oscillator and an open circuit comprising a radiator, the product of the effected capacity and effective inductance in each of the two circuits being the same, substantially as and for the purpose described.

[Matter enclosed between rules erased in copy.]

[Insert B⁶]* Cancelled.>

Respectfully Submitted, Betts, Betts, Sheffield & Betts, Attorneys for Marconi.

[fol. 3550] UNITED STATES PATENT OFFICE, ROOM 91

In the Matter of the Application of GUGLIELMO MARCONI, for Patent for APPARATUS FOR WIRELESS TELEGRAPHY; filed November 10, 1900; serial No. 36,010.

New York, July 5th, 1901.

Hon. Commissioner of Patents, Washington, D. C.

SIR:

In the above-entitled matter, we authorize and request the following amendment of the substitute Specification, filed July 1st, 1901;

Page 8, after line 2, please insert the following:

Sub. D′. A′ [Sub. B′].* Cancelled

A′ "(4). The total length of the primary d is 1.50 "metres, and it is bent round a square of insulating "material d^2, of which the side is .3048 metres long, "while the secondary d′ consists of six turns or "squares, each lying on each side of the primary in "one layer. The insulation of both primary and sec-"ondary is the same as in No. 1."

Per D.

"(5). The primary consists of ten insulated wires each 1.5 metres long, wound side by side in one layer "and connected in parallel, each wire making one

"turn on a square frame, similar to that described "for transformer (4). Over the primary layer is "put a covering of paper, 1 m. m. thick, and upon "this is wound 48.64 metres of wire. The winding "is arranged in layers, the number of turns in each [fol. 3551] "successive layer being, in the first layer "(that nearest the primary), nine; in the second, "eight; in the third, seven; in the fourth, six; in the "fifth, five; in the six, two. The insulation is the same " as No. 1.

"(6) The primary consists of seven wires, wound "side by side, each wire making one turn on a square "frame as used for transformer No. 4. The seven "wires are joined in parallel and the length of each "is 1.50 metres. Over this primary layer is wound "a secondary 30.4 metres long, the winding being ar-"ranged in layers, the number of turns in the suc-"cessive layers being, in the first layer, seven turns; "in the second, six; in the third, five; in the fourth, "four."

"The transformers may be placed in an oil-bath, "especially if the turns are at all numerous."

Page 9, after the last line, please insert the following:

Per D.

A² "A fifth form of induction-coil may have a sec-"ondary consisting of 73.15 metres of wire wound, in "one layer, on a tube 5 cms. in diameter; said sec-"ondary being at its middle point, the wire being "12 m. m. in diameter, single silk-covered. There are "preferably two primaries, each consisting of 2.75 "metres of wire .7 m. m. in diameter wound on tubes "6.5 cms. external diameter. The two primaries are "placed symmetrically, side by side, one over each "half of secondary, and joined in parallel."

Sub. C″

"A sixth form of induction-coil, may have a sec-"ondary consisting of 48.64 metres of single silk-"covered copper-wire, .37 m. m. in diameter, wound "on a tube of 9.6 cms. diameter, in one layer, and is "cut at its middle point. Symmetrically over the

"middle portion of the secondary is wound the pri-"mary 3.64 metres long, of wire .7 m. m. diameter, "single silk-covered."

"A seventh form of induction-coil, may have a "primary consisting of four wires, each 3.04 metres "long, wound in four layers and joined in parallel, "the layers being one under the other. The pre-

[fol. 3552] "ferred wire is .71 m. m. in diameter in-"sulated with a single covering of silk. The second-"ary, which is wound on a tube 3.3 cms. external "diameter, consists of 21.24 metres of wire, .12 m. m. "diameter, insulated with a single covering of silk. "The secondary is divided at its middle point, and "the primary is placed symmetrically inside of the "secondary."

Page 11, before the paragraph commencing "It will be observed", please insert the following paragraph:

Cancelled Per C.

A[3] "Note. In tune No. 9, a small condenser, having "an approximate capacity of .0008 microfarad, is "inserted between the lower end of the receiving "aerial conductor and the induction-coil".

Yours Respectfully, Betts, Betts, Sheffield & Betts,
Attorneys for Marconi.

[fol. 3553] 2—260

Div. —, Room 91

Address only "The Commissioner of Patents, Washington, D. C.," and not any official by name.

Paper No. —

All communications respecting this application should give the serial number, date of filing, title of invention, and name of the applicant.

Department of the Interior, United States Patent Office

Washington, D. C., August 12, 1901.
Mailed " " "

Guglielmo Marconi, c/o Betts, Betts, Sheffield & Betts, 120 Broadway, New York, N. Y.:

Please find below a communication from the Examiner in charge of your application No. 36,010, filed Nov. 10, 1900, for Apparatus for Wireless Telegraphy.

F. I. Allen [Thomas Ewing],* Commissioner of Patents.

In response to the amendments of July 3 and 8, 1901, the following action is had:

In the first paragraph of page 4 of the specification the definitions of persistent oscillators and good radiators are not sufficient. In general, a circuit which is a persistent oscillator is a poor radiator of electro-magnetic waves, and inasmuch as applicant states that his aerial circuit is the same in period as the primary circuit in which the oscillations are generated, it appears that said aerial circuit would likewise be a persistent oscillator and therefore a poor radiator. Applicant is required to further explain this feature of his invention, and accordingly claims 2, 3, 7 and 8 are objected to.

It is suggested that the word "pending" be cancelled at the end of the sixth line from the bottom on page 5.

It is asked whether the unit be the centimeter or inch used in giving the diameter of the wire as mentioned in line 15 of page 7.

[fol. 3554] J', used in the first paragraph of page 8 should be j'. It is thought also that in the third line of the same paragraph 71m. m. is an error.

It is thought that a circuit attuned to a certain freuquency will not respond to the current of frequencies which are harmonics of the fundamental to which the circuit is attuned. Consequently, claim 1 is objected to.

Claim 11 is objected to as alternative in form, having both the oscillation producer and imperfect contact as elements in the primary circuits, whereas, by the limitation, the condenser in shunt around the primary coil limits the claim in the structure shown in figure 2, where no oscillator has been shown.

Claims 16 and 17 are not patentable inasmuch as they are drawn to an employment or use which is not comprehended in the patent statutes as patentable matter.

Claim 16 is further objectionable by the use of the phrase "and therefore the persistent oscillator" which is argumentative in form.

G. C. Dean, Examiner Div. 16.

C. D. E.

93—369-373

[fol. 3555] UNITED STATES PATENT OFFICE

Room 91

In the Matter of the Application of GUGLIELMO MARCONI, for Patent for Apparatus Employed in Wireless Telegraphy. Filed Nov. 10, 1900. Serial No. 36,010

December 6th
New York, [October]* ^ 1901.

Hon. Commissioner of Patents, Washington, D. C.

SIR:

The Examiner's letter of August 12th has been received.

We authorize and request the following amendments of the substitute Specification and Claims:

Page 7, line 26, after "metres", erase the period, and add the following:

B½. "and the core or block on which both primary and secondary are wound is .3048 metres wide".

Pages 8, line 4, before "with", insert the following: "wound on a cylinder 10.64 C.M. in diameter".

Same page, line 25, before "wound", please insert.

(not entered) "joined to 13.41 metres of silk-covered (repetition) copper wire, .37 m. m. in diameter.

Please substitute the following in place of the paragraph beginning (4)", and ending" in No. 1", page 1 of the Amendment dated July 5, 1901;

[fol. 3556] Per D

B'. "(4). The total length of the primary d is 1.50 "metres, and it is bent round a square of insulating "material d^5, of which the side is .3648 metres long, "while the secondary d' consists of six turns or "squares, three lying on each side of the primary in "one layer. The insulation of both primary and sec-"ondary is the same as in No. 1."

[Matter enclosed between rules erased in copy.]

[*Words and figures enclosed in brackets erased in copy.]

Cancel claims 1, 2, and 3, and substitute the following:

Cancelled per C

B^2. "1. A system of electric wave telegraphy, in which the transmitter and the receiver each contains an oscillation-transformer, the time period of electrical oscillations in all the circuits of the transformers being the same or harmonies of each other, substantially as described.

2. A system of electric wave telegraphy, in which the transmitter and the receiver, each contains an oscillation-transformer, one circuit of which is a persistent oscillator and the other a good radiator or absorber of electrical oscillations, substantially as described.

3. A system of electric wave telegraph, in which the transmitter and the receiver each contains an oscillation-transformer, one circuit of which is a persistent oscillator, and the other a good radiator of electrical oscillations, all circuits having the same time period or being harmonies of each other, substantially as described."

[Matter enclosed between rules erased in copy.]

Cancel Claim 8, and substitute the following:

Cancelled per C

B^3. "8. In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a transmitting-station, of an electrical circuit, containing the primary of the oscillation transformer, and a condenser; a signalling instru [fol. 3557] ment controlling the oscillator; and an open circuir, constituting a good radiator, and containing the secondary of the oscillation transformer and a variable inductance, substantially as and for the purpose described."

[Matter enclosed between rules erased in copy.]

Claim 9, line 9, change "effected", to read "affected".
Claim 10, line 9, change "effected", to read "affected".
Cancel Claim 11, and substitute the following:

Cancelled per C

B[4]. "11. At a station employed in wireless telegraphy, the combination, with an oscillation-transformer, of an open circuit comprising an aerial conductor connected with a variable inductance; a connection from said inductance to one coil of the transformer; a connection from the other end of said coil to capacity which may be the earth; a shunt around said coil and containing a condenser; and electrical connections from the other coil of the oscillation-transformer to means affected by electrical oscillations, substantially as and for the purpose described."

[Matter enclosed between rules erased in copy.]

Claim 16, lines 1 and 2, erase "employment", and substitute "combination". Same Claim, line 6, erase "therefore", and substitute "constituting". Same Claim, line 8, erase "therefore", and substitute "constituting".

Cancel Claim 17, and substitute the following:

Cancelled per C

B[5]. "17. In a system of electric wave telegraphy, the combination, at a transmitting-station, of a closed circuit comprising a persistent oscillator and an open circuit comprosing a radiator, the product of the effective capacity and effective inductance in each of the two circuits being the same, substantially as described.

[Matter enclosed between rules erased in copy.]

[fol. 3558] Add the following claims:

Cancelled Per C

B[6] 18. The method of communicating intelligible signals by tuned Hertz oscillations, consisting in adjusting the product of effected inductance in the oscillation-producing circuit and in the radiating cir-

cuit at a transmitting-station of a wireless telegraph apparatus, so as to be substantially the same, substantially as described.

19. The method of communicating intelligible signals by tuned Hertz oscillations, consisting in adjusting the time periods of electrical oscillations in the oscillating-producing circuit and in the radiating circuit at a transmitting station of a wireless telegraph apparatus, so as to be the same or harmonics of each other, substantially as described.

[Matter enclosed between rules erased in copy.]

The Examiner's letter requires fuller definitions of "persistent oscillators" and "good radiators", as found on page 4 of our substitute Specification, and criticises our statement that when the primary circuit is a persistent oscillator, at the transmitting-station, the aerial-circuit is a good radiator. The Examiner apparently bases this criticism that if the time-periods of the primary and aerial circuits are the same, the aerial would be a persistent oscillator and therefore a poor radiator.

In response to this, we would state that the statement made by Mr. Marconi is correct, and is based upon the known fact that vibratory body can be set into vibration either by its fundamental note or by any harmonic. A cir- [fol. 3559] cuit attuned to a certain frequency which is a harmonic of its own, just as a violin string can be set in motion by a tuning-fork which is sounding the first harmonic. Hence, if two electrical circuits are associated with one another, one being a persistent oscillator and capable of storing up a large amount of electrical energy because it has a large capacity, this can be associated with another circuit having the same time-period of vibration but which may be more or less a good radiator according to its form. The radiative power of the circuit may be altered by suitably proportioning the aerial without changing the time-period which depends upon its capacity and self-induction. The radiative power is independent of the time-period. In point of fact, two circuits may have the same time period but very different radiative power.

An early allowance is requested.

Respectfully Submitted, Betts, Betts, Sheffield & Betts, Attorneys for Applicant.

[fol. 3560] Serial No. 36010

2—260

Div. —, Room 91

Address only "The Commissioner of Patents, Washington, D. C.," and not any official by name.

Paper No. —!

All communications respecting this application should give the serial number, date of filing, title of invention, and name of the applicant.

Rej.

Department of the Interior, United States Patent Office, Washington, D. C.

Feb. 11, 1902.
Mailed " " "

Guglielmo Marconi, Care, Betts, Betts, Sheffield & Betts.

Guglielmo Marconi, Care, Betts, Betts, Sheffield & Betts, 120 Broadway, New York, N. Y.

Please find below a communication from the Examiner in charge of [the]* your application [of]* filed Nov. 10, 1900, Ser. no. 36,010, for Apparatus for Wireless Telegraphy.

F. I. Allen, Thomas Ewing, Commissioner of Patents.

This case has been considered as amended Dec. 9, 1901. Applicant's argument has been carefully considered and though difficult of interpretation by reason of grammatical defects, and also because of what seems to be a discontinuity of idea, it is correctly or otherwise interpreted by the examiner to mean that the fundamental of the aerial conductor is a harmonic of the local primary or *vice versa*, and that such a relation necessarily requires that the vibrating body of fundamental periodicity have constants such as cause it be a persistant oscillator and the aerial conductor electrical constants which make it necessarily a good radiator.

[*Words and figures enclosed in brackets erased in copy.]

The possibility of such a construction having been clearly set out on pages 7 and 8 of the Work of Hertz, by Oliver Lodge, The Electrician Company, London, 1894, and applicant's theory and explanation in the original and in the substitute specification being in accord with Lodge's statements, it is decided that the objections raised heretofore were not well taken and all further explanation is waived.

The original specification on page 2, line 28, having described the closed circuit primary as a "good conserver", it is believed that the substitute specification was not incor-
[fol. 3561] rect in describing the closed circuit primary as a persistent oscillator as the two terms are synonymous.

The original specification has been carefuly compared with the substitute specification of July 3, 1901, and it is found that both describe three forms of oscillation transformers and four forms of induction coils. The amendment of July 8th inserts in the specification a description of three more transformers, namely 4, 5 and 6, and three additional induction coils, namely 5, 6 and 7, as well as a small condenser which may be inserted between the lower end of the receiving aerial and the induction coil. The amendment of Dec. 9, 1901, cancels the description of transformer 4 and inserts in lieu thereof another description of the same. The original specification describes six tunes while the substitute specification, after setting out the constants of said six tunes, adds thereto the constants of three additional ones, namely 7, 8 and 9. If the specific modifications of these transformers and inductions coils are merely special cases, clearly deducible from the principles and illustrations found in the original specification they must be held to constitute an unnecessary amplification of what is already sufficiently disclosed. If on the other hand, they have some added value or significance they involve new matter and are therefore inadmissible for that reason. It is noted that these modifications were not added until after the publication of applicant's British patent No. 7777 of 1900, about the 1st of May, 1901, which described the same.

The amendment of Dec. 6, 1901, orders an insertion after "with", line 4 of page 8, but the word "with" is not found in said line.

[fol. 3562] Page 3, lines 25 to 26, refers to a condenser similar to *e* which it is stated may be included in the return connection between the parts referred to in the preceding

sentence. This modification should be illustrated if the description is to be retained.

Page 5, line 22 cancel "pending".

Page 7, line 15, insert mm after .889.

Page 8, line 18, change J' to j'. Line 20, change 71 to .71. Same line, after "core" insert the material of which the core is formed.

Page 9, fifth line from the bottom, after "tube" insert the material of which the tube is formed.

The tables are indefinite because the fourth column of the first table in giving the constants of the tunes 1, 3, 5 and 6, seem to imply that there is no inductance in the circuit, whereas it is probably meant that all of the turns of *g* have been cut out; and because the second table in the last column thereof in giving the constants of tunes 1, 2 and 3 seem to imply the same thing.

Claims 4, 9, 10, 11, 12, 13, 14 and 15 are rendered objectionable by the argumentative phrase "capacity which may be the earth". It is not the province of the claims to explain the terms thereof, but explanation of these terms should be given in the specification. The words "which may be the earth" should be cancelled.

Claim 10 is objected to because it is alternative both in substance and in form because it covers either the transmitter or the receiver. This double meaning is given to it by the 8th line thereof.

Claims 18 and 19 cannot be considered as they are drawn to a method. Division is required under Rule 41.

The following references are cited in rejecting the claims:

[fol. 3563] British patents to

Thompson, 22020, Nov. 3, 1899;
Braun, 5104, Mch. 8, 1899;
Braun, 1862, Jan. 26, 1899;
Braun, 1863, Jan. 26, 1899.

Telegraphy, Wireless,

all of which show oscillation transformers, the primaries of which are persistent oscillators, while the secondaries are good radiators; the British patents to

Brown, 14,449, July 13, 1899,
Wilson et al., 10,153, May 13, 1899, see figure 8,

and the American patents to

Lodge, 609,154, Aug. 16, 1898.
Marconi, 627,650, June 27, 1899.
Telegraphy, Wireless,

which show that it is old to tune a receiver to a transmitter; and the patents to

Marconi, 647,007, Apl. 10, 1900;
Marconi, 647,008, Apl. 10, 1900;
Marconi, 647,009, Apl. 10, 1900;
Marconi, 668,315, Feb. 19, 1901, filed July 17, 1900,

which show that it is old to provide a receiver with an oscillation transformer, one circuit of which is a persistent oscillator and the other a good absorber of electrical oscillations.

Claim 1 is rejected on the first set of references cited because in each of the systems therein set out "the time period of *electrical oscillations* in all the circuits of the transformers" may be the same, or the oscillations of the secondaries may be harmonics of the primaries. This claim covers a very different structure from that called for by claim 3. The statement above quoted from claim 1 does not imply tuning of the circuits. By forced oscillations the time periods would be the same in any of the patents cited against the claim. The claim is further indefinite because it states that the oscillations may be the same or harmonics of each other, but it is not known whether it is [fol. 3564] meant that the secondary of the transmitter and both primary and secondary of the receiver are harmonics of the primary of the transmitter, or whether the primary and secondary of the transmitter have the same period and the primary and secondary of the receiver are harmonics of the same, or whether they are all the same.

Claim 3 correctly covers the disclosure of the specification by setting out that "all *circuits* have the same time period", which of course can only be accomplished by proportioning capacity and inductance, that is by tuning. The claim is met by the first group of references, which show the oscillation transformer &c., in view of the fact that the second group of references shows that it is old to tune a receiver to a transmitter. It is considered that it would not involve invention in view of the latter patents to tune the two circuits of the transmitter to each other, or to tune the two cir-

cuits of the receiver to each other, the two pairs being in tune. This claim is furthermore indefinite for the reason set out in connection with claim 1.

Claim 2 is rejected on the first group of references taken in connection with the four patents to Marconi last cited. The claim calls for nothing more than the use of these receivers of Marconi with the transmitters shown in the British patents to Thompson and Braun.

Claim 4 is indefinite because of the last five lines thereof. By changing the punctuation marks, that is, by changing the comma after "inductance", in the third line from the end, to a semicolon and by cancelling the comma after "end" in the same line, it is readable on figure 1. As the claim stands at present it calls for the inductance *g* between the secondary *d'* and the earth. The claim should be rewritten. [fol. 3565] Claim 7 is rejected on Thompson or the three patents to Braun cited.

Claim 8 is incomplete without the oscillator. This oscillator is merely referred to incidentally instead of being made an element of the claim. The claim, however, is rejected on the references cited against claim 7.

Claim 11 is incomplete without including positively "means affected by electrical oscillations" which as the claim stands is merely brought in by inference as an element.

Claims 16 and 17 are rejected on the references cited against claim 3.

G. C. Dean, Examiner, Div. 16.

G. K. W.

[fol. 3566] Serial No. 36010. Paper No. 7

Am'dt C. & Aff.

Filed May 1, 1902

United States Patent Office

In the Matter of the Application of GUGLIELMO MARCONI, for Apparatus for Wireless Telegraphy, Serial No. 36,010, Filed November 10. 1900

New York,
April 28th, 1902.

Hon. Commissioner of Patents, Washington, D. C.

SIR:

In the matter of the above-entitled Application, we authorize and request the following amendments to the Specification and Claims:

Page 2 of the amendment of July 5, 1901, cancel lines 24 to 32, inclusive, and substitute the following:

C". "Other forms of transformers which may be employed by me are described and claimed in my British Patent No. 7,777 of 1900".

Page 3 of said amendment of July 5, 1901, cancel lines 1 to 12, inclusive.

(Not entered repetition.)

Specification, page 8, line 5, before "with" insert "wound on a cylinder 10.64 cm. in diameter".

Page 3, lines 24, 25 and 26, cancel the sentence beginning "A similar", and ending "said parts".

Page 5, line 22, cancel "pending".

Page 7, line 15, insert "mm." after ".889".

Page 8, line 18, change "J" to read "j". Same page, [fol. 3567] line 21, change "71" to read "and 71". Same line, after the word "core", insert "of ebonite or other insulating material."

Cancel Claims 1, 2, 3, 4, 7, 8, 11, 16, 17, 18 and 19.

Renumber Claim 5 to read 9.

Renumber Claim 6 to read 10.

Renumber Claim 9 to read 11.

Renumber Claim 10 to read 12.
Renumber Claim 12 to read 13.
Renumber Claim 13 to read 14.
Renumber Claim 14 to read 15.
Renumber Claim 15 to read 16.

Claim 13 (new number), line 6, cancel "which may be the earth".

Claim 15 (new number), lines 5 and 6, cancel "which may be the earth".

Claim 16 (new number), line 6, cancel "which may be the earth".

Please insert the following Claims:

Sub D²

C². "1. At a transmitting-station in a system of wireless telegraphy, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected to an oscillation-producing circuit which includes a condenser, the oscillation period of the two circuits being in accord with each other, substantially as described.

"2. At a transmitting-station in a system of wire- [fol. 3568] less telegraphy, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected to an oscillation-producing circuit which includes a condenser, and means for adjusting the oscillation period of the two circuits connected with the transformer to bring them into accord with each other, substantially as described.

Sub D²

C². "3. At a transmitting-station in a system of wireless telegraphy, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected to an oscillation-producing circuit, and an adjustable

condenser located in the last named circuit, substantially as described.

"4. At a transmitting-station in a system of wireless telegraphy, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and a variable inductance located in the said circuit, the primary of the transformer being connected to an oscillation-producing circuit which includes a condenser, substantially as described.

"5. At a transmitting-station in a system of wireless telegraphy, the combination of a transformer whose secondary is connected to an open circuit of a radiating conductor at one end and capacity at the other end, a variable inductance located in the said circuit, the primary of the transformer being connected to an oscillation-producing circuit, and an adjustable condenser located in the last-named [fol. 3569] circuit, substantially as described.

"6. At a station employed in a system of wireless telegraphy, the combination of a transformer whose secondary is connected to an open circuit of an aerial conductor at one end and capacity at the other end, and whose primary is connected to a closed circuit which includes a condenser, the oscillation period of the two circuits being in accord with each other, substantially as described.

Sub. D

C. "7. At a station employed in a system of wireless telegraphy, the combination of a transformer whose secondary is connected to an open circuit including an aerial conductor at one end and capacity at the other end, and whose primary is connected to a closed circuit which includes a condenser and means for adjusting the oscillation period of the two circuits connected with the transformer to bring them into accord with each other, substantially as described.

"8. A system of wireless telegraphy, in which the transmitting-station and the receiving-station each contains an oscillation-transformer, one circuit of

which is a persistent oscillator and the other a good radiator of electrical oscillations, the oscillation period of the circuits at the other station, substantially as described."

[Matter enclosed between rules erased in copy.]

[fol. 3570] Argument

With reference to the position of the Examiner that it would not involve invention, in view of the Patents of Marconi which describe the desirability of tuning a distant receiving instrument so as to correspond with the tune of a transmitting instrument, to tune the two circuits of the multiple-circuit transmitter to each other or to tune the two circuits of a multiple-circuit receiver to each other, we would respectfully answer as follows:

It is very plain that the necessity or desirability of tuning the two circuits of a transmitter to each other or making them accord to each other in their natural period of oscillation, is not an obvious suggestion, from prior descriptions, of desirability of tuning a transmitter to a receiver, as is seen from the fact, although the English Patent of Thompson, No. 22,020 of 1899, describes a two-circuit transmitter, yet the inventor makes not the faintest suggestion of the desirability of having the periods of oscillation accord with each other, and although Mr. Marconi himself, in his Patent No. 627,650, describes a two-circuit receiving instrument, yet he did not make any suggestion that it would be of advantage to make the periods of oscillation of the two circuits accord.

As a matter of fact, the desirability and utility of such an arrangement did not occur to him.

Practical experience has, however, demonstrated that the expedient of making the periods of oscillation of the two circuits, both of the transmitter and the receiver, accord [fol. 3571] with each other, is of very high importance; and in view of the fact that the art of wireless telegraphy is as yet commercially in its infancy, and the proper conditions for effective transmission can only be ascertained by most careful and intelligent experimentation, it would seem clear that this feature of the present invention is not one which was at all obvious to people skilled in the art, and, in fact, was not obvious to the most learned experimenters in this particular art.

We trust, therefore, that the objection will be reconsidered.

With reference to the Examiner's rejection of the Application upon reference to the British Patents to Braun and Thompson, we submit herewith an affidavit of Mr. Marconi, which shows that Dr. Braun's invention did not contemplate the possibility of bringing the two circuits at each station into accord with each other, much less the bringing of two stations into accord, each station containing two circuits. Mr. Marconi's affidavit also deals with the Examiner's rejection upon reference to the prior Marconi patents, and points out that those patents do not speak of or show the two circuits arranged to be brought into accord with each other.

An early allowance is requested.

Respectfully submitted, Betts, Betts, Sheffield & Betts, Attorneys for Applicant.

[fol. 3572] Serial No. —

Paper No. 5

Amendment

Filed —— —, 190-

UNITED STATES PATENT OFFICE

Room 91

In the Matter of an Application of GUGLIELMO MARCONI for Apparatus for Wireless Telegraphy. Serial No. 36010. Filed November 10, 1900

UNITED STATES OF AMERICA,
Southern District of New York (ss):

Guglielmo Marconi, being duly sworn, deposes and says as follows:

I am the Applicant named in the above entitled application.

I have carefully read the letter from the United States Patent Office, under date of February 11, 1902, rejecting the claims of my Application upon reference to British Patents No. 22020 to Thompson of 1899, No. 5104 of 1899, No. 1862 of 1899 and No. 1863 of 1899, all granted to Braun, upon

British Patents 14449 of 1899 to Braun and 10153 of 1899 to Wilson, the United States Patents to Lodge 609,154, Marconi 627,650, Marconi 647,007, Marconi 647,008, Marconi 647,009 and Marconi 668,315.

The invention of my above entitled application 36019, relates to the improvement in a system of wireless telegraphy, consisting of the combination, at a station, of a transformer whose secondary is connected to an open circuit of an aerial [fol. 3573] conductor at one end, and to *a* capacity at the other end, and whose primary is connected to a closed circuit which includes a condenser, the oscillation period of the two circuits being in accord with each other.

I am well aware that the employment of a double circuit transmitting apparatus has been described in the British Patents of Thompson and Braun, yet it is perfectly apparent from the statements in those patents that the inventor (Dr. Braun) did not even know or understand *why* the use of double circuits, inductively connected through coils of a transformer, was advantageous. Much less did he understand that there was or could be any advantage in making the two circuits of such inductance and capacity as to have a natural period of oscillation in accord with each other.

I did not myself appreciate the necessity or desirability of such a construction at the time that I invented the two-circuit receiving apparatus described in the United States Patent No. 627,650, and the discovery made by me that the operation of the instrument was greatly improved and its capacity for transmitting and receiving messages at long distances greatly enhanced by causing the circuits to be in accord, was something which was impossible to ascertain, or even to guess at, without careful experimentation.

As a matter of fact, I did carefully experiment before I ascertained the fact, and when I had constructed trans- [fol. 3574] mitting and receiving instruments, having the above named characteristics, I found that the distance to which messages could be intelligibly transmitted was very greatly enhanced, and the distinctness of messages received over shorter distances greatly improved.

G. Marconi.

Subscribed and sworn to before me this 5th day of April, 1902. James J. Cosgrove, Notary Public, New York County. (Notarial Seal.)

[fol. 3575] 2—260

Div. —, Room 91

Paper No. —

Address only "The Commissioner of Patents, Washington, D. C.," and not any official by name.

All communications respecting this application should give the serial number, date of filing, title of invention, and name of the applicant.

Department of the Interior, United States Patent Office

Washington, D. C., June 3, 1902.
Mailed " " "

Guglielmo Marconi, Care, Betts, Betts, Sheffield & Betts, 120 Broadway, New York, N. Y.

Please find below a communication from the Examiner in charge of your application Ser. No. 36,010, for Apparatus for Wireless Telegraphy, filed Nov. 10, 1900.

F. I. Allen, [Thomas Ewing],* Commissioner of Patents.

This action is in response to the communication filed May 1, 1902.

Applicant should either complete his response to the requirement of the second paragraph of page 2 of the last office letter or give a satisfactory reason for refusing to do so. It is noted that he has cancelled only the description of induction coils 6 and 7.

Applicant should also complete his response to the requirement of the last paragraph of page 3 of the last office letter or give satisfactory reason for his refusal. In this connection present claims 9, 10, 11, 12, 14 and 16 are open to the same objection.

Claims 11 and 12 are alternative in form for the reason given in the last office letter, paragraph 1, page 4, in connection with the then claim 10, now claim 12, namely that they are capable of covering both receiver and transmitter.

Claim 15 which includes *any* imperfect conducting device and its accessories, is allowed.

[*Words and figures enclosed in brackets erased in copy.]

All the other claims are rejected on Tesla, 649,621, May 15, 1900, division of 645,576, Mch. 20, 1900, filed Sep. 2, 1897. On page 3, lines 113 to 125, the details of device G are given. This is an electrical oscillator comprising an [fol. 3576] alternating current generator charging a condenser and an interrupter, which is a spark gap, for discharging the same. The primary of a transformer [condenser]* is fed by this oscillation producing circuit. The secondary is connected to the ground at one end and to an elevated conductor at the other. The periods of the primary and secondary circuits are in accord with each other.

Exr.

Claims 4, 13, 14 and 16, which specify a variable inductance and means for adjusting the inductance, are not patentable over Tesla because Lodge, of record, has shown that it is old to adjust the period of a circuit by a variable inductance; and claims 3 and 5, which specify an adjustable condenser, are not patentable over Tesla because applicant has shown in his prior patent No. 627,650 that this adjustment may be produced by a variable condenser. Since it is impossible to exactly calculate the values of to the electro magnetic constants of two circuits for the purpose of making their time periods agree, it is fair to assume that the electrical oscillator of Tesla must necessarily be made with an adjustable inductance or condenser, or both.

G. C. Dean, Examiner, Div. 16.

G. K. W.

[fol. 3577] Department of the Interior, United States Patent Office

Washington, D. C., Oct. 13, 1903.

Petition:

Application of G. Marconi. Serial No. 36,010

Invention: Apps. for Wireless Telegraphy

Referred to the Examiner in charge of Division 16, who is directed to file an answer on the — day of ——, which answer shall exhibit the reasons, if any, why the request of the petition hereto attached should not be granted.

F. I. Allen, Commissioner of Patents.

[*Words and figures enclosed in brackets erased in copy.]

[fol. 3578] Serial No. 36010

Paper No. 9

Petition to Revive Am'dt. D

Filed Oct. 12, 1903

Amend. D

Docket Clerk, Oct. 12, 1903. U. S. Patent Office

United States Patent Office

Room 91

In the Matter of the Application of GUGLIELMO MARCONI, for Patent for Apparatus for Wireless Telegraphy: Serial No. 36010; filed November 10, 1900

Petition to the Commissioner

New York, October 6, 1903.

To the Commissioner of Patents, Washington, D. C.

SIR:

Your petitioners aver:

First: That they are the Attorneys for the applicant above named.

Second: That said Application was filed on or about November 10, 1900.

Third: That your petitioners were informed, by Office letter bearing date the 3rd day of June, 1902, that (1) Claims 1, 2, 3, 4, 5, 6, 7, 8, 13, and 16, were met by certain references which were given: (2) that Claims 9, 10, 11 and 12 were directed to matter apparently novel; and (3) that Claim 15 was allowable.

[fol. 3579] Fourth: That the said Application is owned by Marconi's Wireless Telegraph Company, Limited, by virtue of an Assignment recorded in the United States Patent Office, on November 10, 1900, in Liber B[63], page 210, Transfers of Patents.

Fifth: That the points raised by the Examiner in the said letter of June 3rd 1902, were extremely technical, and it

was necessary to refer said letter to Mr. Marconi, who has had the greatest experience with those problems which deal with the prevention of interference in the receipt of messages by electrical waves or oscillations. That, at the time of the receipt of said letter of June 3rd, 1902, Mr. Marconi was not in the United States, nor did he come to America until the latter part of December, 1902, when he was in Canada, actively engaged in establishing wireless telegraphic communication between the station at Glace Bay, and the station at Poldhu, in Cornwall, and in response to a cablegram from Glace Bay, at Mr. Marconi's request, your petitioners, early in January, 1903, sent him a complete set of the papers, in connection with the Application, serial No. 36,010, including the Office letter of June 3rd, 1902. That Mr. Marconi did not arrive in the United States until about January 27th, when he was here for a very short time, in connection with the establishment of telegraphic communication, by electric waves or oscillations, between the American station at Cape Cod, and the station in Poldhu, [fol. 3580] to which task Mr. Marconi was required to give his attention almost exclusively while in America, and which he successfully accomplished; that while he was in New York City, during his visit to America aforesaid, Mr. Marconi's attention was again called, on January 27, 1903, to the matter of the Patent Office action of June 3rd, 1902, in connection with this Application No. 36010, and while he then gave some information in reply, to said letter, he found that it was absolutely necessary to postpone the filing of a complete reply to the said Patent Office letter until he could very carefully examine his records, etc., then stored in England. These records being for this reason entirely inaccessible to Mr. Marconi, delay in amending was unavoidable.

Urgent business calls in connection with installing and perfecting his system of wireless telegraphy in Europe, required Mr. Marconi to leave this country on January 31st, 1903, and he has found himself quite unable, owing to pressure of business, and to illness, to return to this country until the present time, and he has also found the demands upon his time to be so great in connection with the various stations embodying his inventions throughout the different parts of Europe, as to prevent his giving full attention to the points raised by the Examiner in said letter of June 3rd 1902, and to prepare the papers and other memoranda

necessary to point out, in detail, the differences existing between his system of wireless telegraphy, and the systems [fol. 3581] and parts of systems of the references cited against his Claims. That after Mr. Marconi's departure to Eurpoe your petitioners wrote to Mr. Marconi, and also to Marconi's Wireless Telegraph Company, Limited, at London, England, asking them to send the required information to this country, namely on January 27th, 1903, and March 20th, 1903. That thereafter, on April 4th, 1903, your Petitioners received from said company a letter to the effect that Mr. Marconi had informed the Company that the papers referred to in our letter of January 27th to him had been dispatched. That the said papers were never received. That not having received the necessary information, your petitioners again addressed a letter to Marconi's Wireless Telegraph Company, Limited, dated May 13th, 1903, urging that the papers above referred to be furnished, and in response to a fourth letter, dated June 5th, 1903, your petitioners were in receipt of a cablegram dated July 3rd, 1903, stating that Mr. Marconi has been ill, but that it is hoped to send the papers on July 20th.

That on August 21, 1903, certain papers were received, but no remarks from Mr. Marconi.

That Mr. Marconi was in New York from September 28th, 1903, to October 3rd, 1903, and then was information from him available.

Fifth: That until the receipt of the papers and the information referred to, your petitioners were unable to file a complete and full response to the Examiner's letter of June 3rd, 1902.

[fol. 3582] That thereafter your petitioners have carefully considered the questions involved, and have prepared and amendment and argument which covers fifteen full-sized typewritten pages, and is completely responsive to the last Office action, and is annexed hereto.

Wherefore your petitioners request that the said Application, serial No. 36010, be revived as a pending Application, and that the Examiner in charge thereof be instructed to reopen the same and enter the amendment hereto annexed.

Respectfully, Betts, Betts, Sheffield & Betts.

While it is believed the foregoing petition and the appended affidavit are sufficient of themselves to warrant the

revival of this application, attention is respecfully directed to the fact that applicant's British patent No. 7777 of 1900 will absolutely preclude the assignees of this valuable invention from filing a new application.

Respectfully, Thos. E. Robertson, Assoc. Attorney.

[fol. 3583] City, County and Southern District of New York, *ss:*

Louis Frederick Holbrook Betts being duly sworn, deposes and says: I am a member of the firm of Betts, Betts, Sheffield and Betts, Attorneys for Guglielmo Marconi, in the matter of the above entitled Application.

Referring to the papers filed in connection with said Application, it will be seen that the last action of the Patent Office, dated June 3rd, 1902, raised certain questions extremely technical, and which required to be referred to a person technically and practically skilled in the art of wireless telegraph, by the employment of Hertzian waves, or electrical oscillations, which is an entirely novel art, of which little is known as to the practical realization, and the theory of which is still unsettled, and more especially was it necessary to refer to such a skilled person, the question of the likeness of the systems of Lodge and of Tesla, when used separately, or when employed together, and it therefore became absolutely necessary, in order to file a complete response to the Examiner's letter, to refer these matters to Mr. Marconi, who has had the greatest experience with the delicate problems of wireless telegraphy, and who has succeeded in solving many of these problems only after the most painstaking efforts, and after having devised many new forms of apparatus and combinations of apparatus. [fol. 3584] Inasmuch as the Application, No. 36010 especially deals with the problem of preventing interference in the receipt of messages by electrical waves or oscillations, to which question Mr. Marconi has given the most careful and practical study, it was decided to await his arrival in this country before submitting the questions raised by the Examiner's letter to him.

Mr. Marconi did not come to the United States, after the receipt of the Patent Office letter of June 3rd, 1902, until the end of January, 1903, on which occasion his time and atten-

tion were almost exclusively devoted to the establishment of electrical communication between the American station at Cape Cod, and the station at Poldhu, in Cornwall, and to the development of his new receiver, which employs a varying magnetic field for assisting the receipt of electrical oscillations. When Mr. Marconi was in New York, and at all available in connection with his Application No. 36010, the Examiner's letter of June 3rd, 1902, was submitted to him, in connection with the other papers relating to said Application, and was very carefully considered, but Mr. Marconi found himself unable to completely reply to said letter until he could examine his records and data, then stored at London. Inasmuch as he was then called to England, in connection with the operation and protection of his stations in European countries, he requested that he be informed by your petitioners, as to the papers and information necessary to be furnished, in connection with said Application, [fol. 3585] No. 36010, and this was done on January 27th, and later on on March 20th, our firm wrote to Mr. Marconi, and to the Marconi's Wireless Telegraph Company, Limited urging that the information referred to, together with the papers, be sent as soon as possible, and in reply our firm received a letter, on April 11th, 1903, to the effect that Mr. Marconi had informed the Company that the affidavits referred to in our letter of January 27th had been dispatched by the Notary. These affidavits were never received. After waiting a reasonable time for the receipt of these papers which were deemed necessary in connection with the Application No. 36010, we again wrote to the Marconi's Wireless Telegraph Company, Limited, on May 13th, 1903, urging that these papers should be furnished to us, and, in response to a fourth letter, dated June 5th, 1903, we were in receipt of a cablegram, dated July 3rd, 1903, that Mr. Marconi has been ill, and this is the reason why the papers were not sent in response to our last letters.

That thereafter, on August 21st, 1903, we received certain papers, but no remarks from Mr. Marconi. That thereafter, Mr. Marconi was in New York from September 28th to October 3rd, 1903, and then was information from him available. That we thereafter prepared an amendment and argument in reply to the last office action upon the application in question, which amendment, with the argument relating thereto, covers fifteen large typewritten

[fol. 3586] pages, and is completely responsive to the last office action.

It is evident, therefore, that the filing of an amendment in response to the official action of June 3rd, 1902 has been prevented by circumstances beyond the control of the inventor, the owners of the patent, and the attorneys for applicant.

L. F. H. Betts.

Sworn to and subscribed before me this 6th day of October, 1903. Francis White Proscher, Notary Public, Queens Co. Cert. filed in New York County. (Notarial Seal.)

[fol. 3587] United States Patent Office

Room 91

In the Matter of the Application of Guglielmo Marconi, for Patent for Apparatus for Wireless Telegraphy, Serial No. 36,010, filed November 10, 1900

[Amend. D.]

New York, October 6, 1903.

Hon. Commissioner of Patents,
Washington, D. C.

SIR:

Replying to Office action of June 3, 1902, we authorize and request the following amendments of the substituted Specification and Claims:

Cancelled per E

Specification, page 3, line 10, after "station", add "Fig. 9 is a view, similar to Fig. 2, showing the employment of a condenser in the earth connection of the receiving apparatus".

Page 5, after "communicating-system", last line of said page, please add: "A condenser, X (Fig. 9) may be inserted in the open circuit of the receiving-station, between the coil j' and the capacity E".

Page 6, after line 23, please insert the following:

"If preferred, the oscillation-radiating conductor and the oscillation-receiving conductor, or either, may be connected [fol. 3588] to any suitable capacity instead of being directly earthed. On certain rocky islands, it has been found impossible to make what telegraph engineers call a good earth or ground connection, but the apparatus has worked well in such places when, instead of a ground connection, a large metallic surface (plates of zinc, ef about 400 square feet surface, were found useful) placed on the surface of the rocks, has been utilized."

[Matter enclosed between rules erased in copy.]

Cancel the amendment dated July 5, 1901, also the correction thereof contained in our Amendment dated December 6, 1901, and substitute the following:

D[1] "Various forms of transformers, etc., which may be employed by me are described in my British Patent No. 7,777 of 1900."

Page 10, cancel the description of details of tune No. 7, in the tables relative to the Transmitting-station.

Page 11, cancel the description of details of tunes 7, 8 and 9, in the tables relative to the Receiving station.

Cancel Claims 1, 2, 3, 4, 5, 6, 7 and 8, and substitute the following:

D[2] "1. At a station employed in a wireless telegraph system, a signalling-instrument comprising an induction-coil, the secondary circuit of which includes a [fol. 3589] condenser discharging through a means which automatically causes oscillations of the desired frequency; an open circuit electrically connected with the oscillation-producer aforesaid and a variable inductance included in the open circuit, substantially as and for the purpose described.

"2. At a station employed in a wireless telegraph system, an oscillation-receiving conductor, a variable inductance connected with said conductor; a wave responsive device electrically connected with said

conductor and in circuit with a condenser, substantially as and for the purpose described.

D² "3. At a station employed in a wireless telegraph system, a signalling instrument comprising an induction coil, the secondary circuit of which includes a condenser discharging through a means which automatically causes oscillations of the desired frequency, and the primary circuit of which includes a generator; means for varying the primary circuit; an open circuit electrically connected with the oscillation-producer aforesaid, and a variable inductance included in the open circuit, substantially as and for the purpose described.

Substitute F⁵

"4. At a transmitting-station employed in a wireless telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected to a condenser-circuit discharging through [fol. 3590] a means which automatically causes oscillations of circuit and the open circuit being in electrical resonance with each other, substantially as described.

D² "5. At a transmitting-station employed in a wireless telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected to a condenser-circuit discharging through a means which automatically causes oscillations of the desired frequency, such condenser-circuit and the open circuit being in electrical resonance with one another; an induction-coil, the secondary winding of which includes the condenser aforesaid, a source of energy included in the primary winding of said coil, and means for varying the circuit of said primary winding, substantially as described.

[Matter enclosed between rules erased in copy.]

"6. At a transmitting-station employed in a wireless telegraph system, the combination of a trans-

former whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected to a condenser-circuit discharging through a means which automatically causes oscillations of the desired frequency, and means for adjusting the oscillation period of each of the two circuits connected with the transformer to bring them into accord with each other, substantially as described.

Substitute F[6]

"7. At a transmitting-station employed in a wireless telegraph system, the combination of a trans- [fol. 3591] former whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected in series with an adjustable condenser, and a means which automatically causes oscillations of the desired frequency, substantially as described.

[Matter enclosed between rules erased in copy.]

D[2] "8. At a transmitting-station employed in a wireless telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, a variable inductance being included in said circuit [said circuit]* and whose primary is connected to a condenser-circuit discharging through a means which automatically causes oscillations of the desired frequency, substantially as described.

"9. At a transmitting-station employed in a wireless telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, a variable inductance being included in said circuit, and whose primary is connected in series with an adjustable condenser and with a means which automatically causes oscilla-

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* [Words enclosed in brackets erased in copy.]

tions of the desired frequency, substantially as described.

"10. A system of wireless telegraphy, in which the transmitting-station and the receiving station each contains an oscillation-transformer, one circuit of which is an open circuit and the other a closed circuit, the two circuits at each station being in elec- [fol. 3592] trical resonance with each other and in
D[2] electrical resonance with the circuits at the other station, substantially as described."

Renumber Claim 9 to read 11, and cancel "which may be the earth", line 10 of said Claim.

Renumber Claim 10 to read 12, and cancel "which may be the earth", lines 9 and 10 of said Claim.

Cancel Claim 11, and substitute the following:

D[3] "13. At a receiving-station employed in a wireless telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a variable inductance being included in said circuit, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and a condenser in circuit with the wave-responsive device, substantially as described.

"14. At a receiving-station employed in a wireless telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave-responsive device electrically connected with the other winding of the oscillation- [fol. 3593] transformer, and means for adjusting the two transformer circuits in electrical resonance with each other, substantially as described.

D[3] "15. At a receiving-station employed in a wireless telegraph system, the combination of an oscillation transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation receiving conductor at one end and capacity at the other end, a condenser located in said circuit between the coil and the capacity, a wave-

responsive device electrically connected with the other winding of the oscillation-transformer, and means for adjusting the two transformer circuits in electrical resonance with each other, substantially as described.

"16. At a receiving-station employed in a wireless telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, an adjustable condenser in a shunt connected with the open circuit and around said transformer-coil, a wave-responsive device electrically connected with the other coil of the oscillation-transformer, and means for adjusting the two transformer circuits in electrical resonance with each other, substantially as described.

"17. At a receiving-station employed in a wireless telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil [fol. 3594] of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and means included in each of said transformer-circuits, for adjusting said circuits in electrical resonance with each other, substantially as described.

D[3] "18. At a receiving-station employed in a wireless telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end, and capacity at the other end, a variable inductance being included in said open circuit, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and a variable inductance included in circuit with the wave-responsive device, substantially as described.

Cancel Claims 12, 13 and 14.

Renumber Claim 15 to read 19, and cancel "which may be the earth", line 6 of said Claim.

Cancel Claim 16 and substitute the following:

D[4] "20. In a system of wireless telegraphy, a transmitting-station containing an oscillation-transformer, the primary of which is connected to a condenser-circuit discharging through a spark-gap which automatically causes [oscillations]* ^electric waves of the desired frequency, the secondary of said transformer connected to an open circuit including a radiating-conductor, and with a capacity and a coil for charging the condenser aforesaid; a receiving-station containing an oscillation-transformer, the primary of which is connected with an oscillation-receiving conductor and with a capacity, a wave-responsive device connected with the secondary of said transformer, and a receiving-instrument connected with the wave-responsive device, all in combination with means for bringing the four transformer-circuits, two at each station, into electrical resonance with each other, substantially as described.

[fol. 3595]

Cancelled per E

"21. The method of communicating intelligible signals by tuned electrical oscillations, consisting in adjusting the electrical resonance in the oscillation-producing circuit, at a transmitting-station of a wireless telegraph system, so as to accord with the electrical resonance of the radiating-circuit at said station, substantially as described.

"22. The method of communicating intelligible signals by tuned electrical oscillations, consisting in adjusting the time periods of such oscillations in the oscillation-producing circuit and in the radiating-circuit, at a transmitting-station of a wireless telegraph apparatus, so as to be the same or harmonics of each other, substantially as described."

[fol. 3596]

Argument

The formal objections of the Office are met by the changes in the Specification.

Cancelled E

[A new figure (Fig. 9) has been added to the drawings.]*

* [Words enclosed in brackets erased in copy.]

The Claims as now drawn differentiate the present invention from that of Tesla, especially in respect to the apparatus for automatically producing electrical oscillations of desired frequency. In the Tesla Patents cited by the Examiner, the oscillation-producing connections and devices are vaguely described, but are not illustrated. Apparently, they comprise a transformer whose primary was discharged through a condenser and through a *mechanically-operated* break.

Mr. Marconi, on the other hand, discharges the primary throught the condenser circuit and through a sparkgap which *automatically* produces oscillations of desired frequency.

Tesla does not show or describe any means for adjusting the resonance of the two transformer circuits at the transmitting stations.

The apparatus described in the cited Tesla Patents can have no value as references, since they are not workable in wireless telegraphy, and will not work over even 1/100 part of the distance to which oscillations can be sent by Marconi apparatus of the same dimensions.

[fol. 3597] The object apparently aimed at by Tesla, in the cited Patents, is to transmit electrical currents of high potential by conduction through the high and rarified stratum of air, and he states, clearly (in Patent No. 649,621, lines 73, etc., page 2) "that the phenomenon here involved is one of true conduction and not to be confounded with the phenomena of electrical radiation".

Mr. Marconi's apparatus is one for propagating and utilizing radiant energy, and his system of wireless telegraphy depends upon the detection, at a distant station, of these radiated waves, in such a way as to vary the local circuit of apparatus at such station.

Mr. Tesla's apparatus is one for propagating electrical oscillations at the station, conducting them (by the air) to a distance station, and uutilizing the same for light, heat or power, independent of local generators. For this, he requires (page 5, patent 645,576) that the terminals at each station shall be elevated so as to maintain a "moderate" height of 35,000 feet above sea level.

Mr. Marconi has sent oscillations more than three thousand miles, using terminals of only 250 feet.

The arrangement of apparatus figured and described in Tesla's U. S. Patent No. 645,576, dated March 20, 1900, is radically different in function from that shown in Marconi's U. S. Application Serial No. 36010.

In the above mentioned patent, Tesla describes in detail an oscillation transformer the secondary circuit of which [fol. 3598] consists of a flat helical coil of wire generally of considerable length; in some cases he says it would be 50 *miles* in length. The primary circuit was to consist of a few turns concentric with the secondary circuit. He furthermore states that the primary circuit is to be traversed by the discharges of a condenser and the secondary circuit then becomes a seat of high frequency high pressure electromotive forces. It is important to notice that in the specification of Tesla No. 645,576 and in other correlated specifications by Tesla, not one word is said about the application of this oscillation transformer to the production of *electric waves*. Tesla's idea clearly is that he can transmit electric energy through rarefied air; for example, through the upper strata of the atmosphere, if he can introduce into one part of this rarefied air high frequency electric currents, and as he says *conduct* electricity from one place to the other. He proposes to place at two localities oscillation transformers of the kind described to connect one end of each secondary circuit to the earth and the other end to an aerial of insulated wire. At the transmitting end he proposes to set up oscillations of high frequency and high electromotive force, and at the receiving end to draw off in some way not explained in detail the alternating current which has been transmitted through the rarefied atmosphere from the transmitter.

Now this process has no resemblance whatever to the process which is conducted by Marconi's apparatus. In this latter case the transmitter is definitely arranged with the object of throwing off from the radiating wire elec- [fol. 3599] tric or Hertzian waves. Tesla's object is to inject into the upper atmosphere high frequency electric currents and to *conduct* them by means of the rarefied air to the distant place. Tesla never mentions in his specifications the words Hertzian waves or electric waves; his invention is concerned with a totally different process, and his appliances are unsuited for Hertzian wave generation.

Tesla does not mention as important that the primary and secondary circuits of his oscillator should be so ad-

justed as regards inductances and capacity that the product of the two for each circuit is the same. It is true he says the results are "particularly satisfactory" when the primary Coil A¹ with its secondary Coil C¹ at the receiving end is adjusted to vibrate in synchronism with the transmitting Coil A C. (See lines 40-45, page 4, No. 645,576). But this rough statement does not supply the information which Marconi gives.

Again, Marconi describes in great detail the particular shapes and sizes of the oscillation transformers at the transmitting and receiving ends and the other details as to the capacities which are alone effective in enabling him to construct an apparatus for Syntonic Hertzian Wave Telegraphy.

Tesla is not even original in the form of his oscillator. The flat spiral coils which he uses are merely a reproduction of Knockenhauer's spirals figured in nearly every text book on Physics.

Hence we can say as follows:

[fol. 3600] (i) Tesla has never applied his oscillator to the special production of Hertzian waves, but always for the production of high frequency electric currents which he proposes to *conduct* through the air.

(ii) Tesla's flat coil oscillator is not suitable for the production of Hertzian waves, and especially unsuitable for their absorption and reception.

(iii) He gives no explicit instruction for the tuning of all four circuits of the transmitting and receiving oscillation transformers.

On the other hand Marconi sets out:

(i) With the definite idea of producing a practical syntonic Hertzian Wave telegraphy, and this he has practically achieved. He does not operate by means of *Conduction* through rarefied air, but by means of Hertzian Waves produced in the ether.

(ii) He gives explicit details of the oscillation transformers which are quite different in form from Tesla's, and also defines the rules by which Syntonism is secured, by adjusting the capacity and inductance of four different circuits.

Tesla's apparatus taken as a whole is not the equivalent of Marconi's. It could not perform the same duty and if set up exactly as Tesla describes, Syntonic Hertzian Wave telegraphy could not be conducted by it. Hence if it is not equivalent, it is not anticipatory.

The so-called Tesla oscillator is an air core induction [fol. 3601] coil devised for a particular purpose by Tesla. The Marconi oscillation transformer is a quite different form of induction coil devised for transforming oscillations of Hertzian Wave frequency.

There is, therefore, no use of a Tesla Oscillator by Marconi, but only a use of scientific principles, some of which are applied by Tesla for one purpose and some by Marconi for another.

The notion that any sort of transformer with two coils on it, in fact, any air-core transformer can take the place of Marconi's special coils, is quite a fallacy.

An allowance of the Claims is now requested.

Respectfully submitted, Betts, Betts, Sheffield & Betts, Attorneys for Marconi.

[fol. 3602] United States Patent Office

Room 91

Patent Office, Oct. 12, 1903. Div. 16. Filed

In the Matter of the Application of Guglielmo Marconi, for Patent for Apparatus for Wireless Telegraphy: Serial No. 36,010; Filed November 10, 1900

New York, October 6th, 1903.

Hon. Commissioner Patents, Washington, D. C.

Sir:

Please recognize, Thomas E. Robertson, of 605 Seventh Street, Washington, D. C., as our Associate Attorney, in the matter of the above-entitled Application.

Yours respectfully, Betts, Betts, Sheffield & Betts, Attorneys for Marconi.

[fol. 3603] Paper No. 10

U. S. Patent Office, Oct. 15, 1903

Mailed

Department of the Interior, United States Patent Office

Washington, D. C., October 15, 1903.

In the matter of the application of Guglielmo Marconi, for patent for Apparatus for Wireless Telegraphy, filed November 10, 1900, Ser. No. 36,010

Examiner's Statement

This is a petition to revive the above entitled application which became abandoned June 3, 1903, by reason of failure to prosecute the same within one year from the date of the last official action, which was June 3, 1902.

Annexed to the petition is an affidavit by one of the attorneys substantiating the statement of facts alleged by the petition to constitute a showing of unavoidable delay.

These facts are that because of the technical nature of the invention it was necessary to submit the questions raised by the last office letter to Marconi, who was not in the country when the letter of June 3, 1902, was received, and who did not arrive here until the latter part of December, 1902.

No attempt has been made to account for the seven months delay intervening between the receipt of the last office letter and Marconi's arrival in this country. In this connection attention is called to ex parte McElroy, 101 O. G. 2823, in which it was decided that the *delay* must be [fol. 3604] unavoidable and not merely that a *certain portion of the delay* must be unavoidable.

Early in Janaury, 1903, Marconi, who was then at Glace Bay, cabled the attorneys for the record of the application, which was sent to him. Marconi was too busy evidently to attend to the matter until his arrival in the United States on January 27, 1903, at which time he gave the attorneys partial information, but found it necessary to postpone filing a complete reply to the last office letter until he could examine his records in England.

The necessity for consulting these records was apparently caused by the citation of two patents to Tesla, which in the

opinion of the Examiner discloses the invention presented in this application. These patents show in the drawings purely diagrammatic and conventional representations of certain apparatus known for many years as the "Tesla oscillator". Apparently Marconi did not make any serious attempt to find out what these patents really did disclose because he has amended his claims in such a way that they are still readable upon the Tesla patents. This will be hereinafter more fully explained.

Marconi left this country on January 31, 1903, and owing to pressure of business found himself unable to prepare the necessary instruction to his attorneys.

On March 20, 1903, nine and one-half months after the date of the last letter, the attorneys called on the Marconi Company for the necessary information.

On April 4, 1903, ten months after the date of said office letter, the attorneys received a communication from the Company stating that Marconi said he had already sent the papers required. These papers were never received.

On May 13, 1903, eleven months after the date of said [fol. 3605] office letter, the attorneys addressed a letter, which should certainly have been a cablegram, to the Marconi Company urging that the papers be sent and on June 5, 1903, twelve months after the date of said office letter, another such request was sent to said Company.

It would seem that some action based on the partial information obtained from Marconi January 27, 1903, might have been submitted by the attorneys between May 13 and June 3, 1903, that would have saved the case from abandonment.

On July 3, 1903, thirteen months after said office letter, a cablegram was received by the attorneys stating that Marconi had been ill, but hoped to send the papers July 20, 1903.

On August 21, 1903, fourteen and one-half months after the date of said office letter, the desired papers were received, but were accompanied by no remarks from Marconi.

On October 3, 1903, sixteen months after said office letter, Marconi was in New York and then information was received from him.

This petition was then presented on October 13, 1903, sixteen months and ten days after the date of the last office letter and was accompanied by a fifteen page amendment alleged to be completely responsive to the last office action and presumably based on the information imparted by

Marconi to his attorneys. This amendment will be hereinafter more fully described.

Although Marconi alleges that he was so busy with business matters requiring his entire attention, that he was unable to give any of his time to the prosecution of this application, he has nevertheless found time to file four applications for letters patent in this office, namely, 132,974, [fol. 3606] November 28, 1902; 141,398 and 141,399, February 2, 1903; and 172,617, September 10, 1903.

It is by no means unusual that an active inventor is too busy perfecting his inventions and filing applications for later improvements, to devote much of his time to the prosecution of his applications already filed, but such a condition of affairs, it is thought, does not constitute the unavoidable delay mentioned by statute as prerequisite to the revival of an abandoned application.

At this point reference is made to applicant's co-pending application serial number 82,856, filed November 19, 1901. In answer to the rejection of June 21, 1902, the attorneys found it possible to prepare and submit an elaborate amendment although the invention involved matters of technical difficulty of much the same order as those involved in this application.

On October 7, 1903, in said application an affidavit was submitted by Prof. J. A. Fleming, the retained expert of the Marconi Company, explaining certain theoretical matters on which additional information is asked by a previous office letter.

It would seem that the services of this expert were just as available to the Marconi Company in this application as they were in application serial number 82,856 although no attempt apparently was made to call them into requisition when it was found that Marconi was not available.

In view of the foregoing it is thought that the affidavit of the attorneys fall far short of the showing of unavoidable delay covering the entire period contemplated by R. S. 4894 and by Rule 172 as construed by the Commissioner of Patents in the following cases:

[fol. 3607] Ex parte Klenha, 28 O. G., 1272.
Ex parte Pratt, 39 O. G., 1349.
Ex parte Murray, 56 O. G., 1060.
Ex parte McPhil, 56 O. G., 1060.
Ex parte Raeymaekus, 60 O. G., 1749.
Ex parte Heine, 64 O. G., 1006.

It has been the Examiner's practice, however, to overlook much in showings of delay in similar cases where the amendment submitted with the petition has been such as to put an application in condition for allowance without further action on the part of the office and in such cases his favorable recommendations have heretofore been accepted by the Commissioner.

In order to ascertain if such treatment could be accorded in the present case a careful examination has been made of the amendment submitted with this petition. As a result of such examination the following report is made:

Many of the claims are not patentable over Tesla, 645,576, and 649,621, of record, the amendment designed to overcome said reference as well as Marconi's pretended ignorance of the nature of a "Tesla oscillator" being little short of absurd. Ever since Tesla's famous lecture on alternating currents of high frequency delivered before the American Institute of Electrical Engineers in 1891, and repeated in 1892 before the Institute of Electrical Engineers and the Royal Institution, London, the Societe Internationale des Electriciens and the Societe Francaise de Physique, Paris, which lectures have been widely published in all languages, —the term "Tesla oscillator" has become a household word on both continents.

Anyone who has read such elementary text books on physics as are used in the ordinary high school or in the first [fol. 3608] year of a technical college course knows what this term means. Marconi evidently knew in 1897, because he is quoted by Della Riccia in the Rivista di Artiglieria e Genio, Vol. 2, 1898, page 343, as having said that he employed such oscillator and also an Elihu Thomson oscillator in certain early experiments at Dover, but that the results were not so good as those obtained by using an ordinary induction coil.

The Tesla oscillator as a means for generating currents of high frequency and high tension for use in wireless telegraphy was first patented by Dr. Braun (see British patent 1862 of 1899, published January 27, 1900, or Swiss patent, 18577, published November 30, 1899, or German patent, 111,578, filed October 14, 1898).

Braun did not tune the transmitting wire to the period of the oscillator but this is clearly described in the Tesla patents of record (see page 4, 645,576 and the last three lines

of page 1 down to the first ten lines of page 2 of 649,621, see also claims 5, 7, 9 and 10.)

On page 4, of 645,576 it is said that "the primary and secondary circuits in the transmitting apparatus being carefully synchronized, * * *". The term "synchronized" as applied to two circuits is synonymous with the term "tuned". In 649,621 at the point above indicated and elsewhere it is clearly stated that the elevated conductor is so designed and adjusted that the point of maximum potential is coincidental with the end of the wire, that is, the transmitting wire is equal to a quarter wave length of the disturbance in the circuit and consequently of the radiated wave.

This means nothing more nor less than tuning the elevated conductor to the Tesla oscillator, (which is any closed circuit containing a spark-gap, a condenser and an inductance,) inductively associated with said vertical wire. Au- [fol. 3609] thority for this statement may be found in three papers dealing with the theoretical aspects of electrical oscillations and electro magnetic waves, namely:

Ascoli in "Electricista", Rome, August 1897.

Slaby in "Electrician", London, April 25 and May 2, 1902.

Fessenden in "Transactions Amer. Inst. Elec. Engr." December, 1899.

Tuning a closed persistently oscillating circuit with the vertical transmitting wire as well as the advantages resulting therefrom has been described by Pupin in the paper presented before the American Institute, December, 1899, and by Fessenden in patents 706,735 and 706,736, August 12, 1902, where the closed persistently oscillating circuit is *conductively* connected with the open oscillator or good radiator i. e., the transmitting wire, and the same thing has been disclosed by Stone in patents Nos. 714,756 and 714,831, wherein the closed and open circuits are *inductively* connected.

The amendment does, indeed, cancel much of the new matter that has been injected into this case since it was filed but on the other hand more new matter is sought to be added by said amendment. Specifically the amendment to page 5 after the last line thereof specifying that a condenser X may be inserted in the open circuit between the coil j' and the earth E is not justified by the original dis-

closure and is, in fact, an idea borrowed from Stone's patent 737,170, August 25, 1903,—see Fig. 2.

The new figure illustrating this construction is without justification.

The amendment to page 6, line 23, referring to the use of the "artificial ground" is new matter and is an idea taken from Fessenden's patent 706,746, August 12, 1902. [fol. 3610] These features have not been claimed and thus according to the settled practice the amendment would not have been entered if presented during the regular prosecution of the case because an amendment cannot be entered in part, (ex parte Stern, 59 MS. Dec. 254).

The proposed amendment presents a number of apparatus claims and two method claims (claims 21 and 22). Therefore this amendment, if presented during the regular prosecution of the case, would have resulted in an immediate requirement of division and, as decided in ex parte Tichirner, 97 O. G., 187, the business of the office would in such case be best facilitated by refusing to enter the amendment.

As decided in ex parte Morrison 99 O. G., 2969, such an amendment would not have been entered even if presented when the case was alive on the last day of the year allowed by law for the prosecution of the case, in order to save it from abandonment.

It is thus apparent that the amendment accompanying this petition is not even of such character that it may be entered, much less put the case in condition for allowance, and that therefore there is not the same reason for overlooking the deficiencies of the showing made to account for the delay that might exist were the amendment one which would put this case in condition for allowance.

The associate attorney has presented a brief argument to the effect that failure to revive this case will work irreparable injury to the assignees because Marconi's British patent No. 7777 of 1900 filed April 26, 1900, operates as a bar to a new application for what he calls "this valuable invention".

It is true that said British patent as well as other foreign patents so operates and it is true that this is a valuable [fol. 3611] invention, but, in the opinion of the Examiner, the references above cited and also numerous other references, some of which are hereinafter set forth, effectually dispose of the idea that this is a valuable *application*, however valuable may be the invention disclosed therein, be-

cause any patentable claims which this application will support in view of the state of the art must necessarily be of the most limited character.

Some of these references, above referrred to, which disclose a closed persistently oscillating circuit known as the D'Arsonval or the Oudin oscillator (a modification of the Tesla oscillator) inductively associated with an open or radiating circuit attuned thereto for the purpose of transmitting electro magnetic signal waves, are

L'Industrie Electrique, Paris, #156, June 25, 1898, page 363.

L'Electrician, Paris, Vol. XVI, #406, October 8, 1898, page 235 and especially page 237, paragraph 2, second column.

Notice General sur les Curants de Haute Frequence et de Haute Tension, published by E Ducretet, 75 Rue Claude-Bernard, October, 1898, pages 9, 14-16.

La Telegraphie Hertzienne Sans Fil, Ducretet, November-December, 1898, page 5.

La Telegraphie Sans Fil,—Graffigny, published by Barnerd and Co., Paris, January 1, 1900, Fig. 40, 153.

La Revue Scientifique et Industrielle de l'Annee, Annees 1898-1899, by Breton, published by Barnerd & Co., Paris, 1900, p. 35.

It is therefore recommended that this petition be denied.
Very respectfully, Wm. A. Kinnan, Actg. Examiner, Division XVI. G. K. W.

[fol. 3612] Serial No. 36,010

Paper No. 11

Supplemental Petition and Proposed Amendment E
Filed Oct. 24, 1903

Amend E

United States Patent Office

Room 91

In the Matter of the Application of GUGLIELMO MARCONI for Patent for Apparatus for Wireless Telegraphy Serial No. 36,010. Filed November 10, 1900.

Before the Commissioner of Patents by Petition

CITY AND COUNTY OF NEW YORK,
Borough of Manhattan, ss:

LOUIS FREDERIC HOLBROOK BETTS, being duly sworn, deposes and says:

I am the Louis Frederic Holbrook Betts who has heretofore made an affidavit in this matter, verified October 6, 1903, and I have read the recommendation of the Examiner that the petition to revive the above entitled application be denied.

In the first place, I desire to point out that the Examiner is in error in stating that Mr. Marconi "did not arrive here until the latter part of December, 1902", if by "here" the Examiner means the United States. It is distinctly pointed out in the petition, and in my affidavit, that Mr. Marconi arrived in Canada in December, 1902, but did not arrive in New York until the 27th day of January, 1903. Therefore it was not possible to confer with Mr. Marconi until the 27th of January, 1903, on which very day we did promptly bring this matter to his attention.

The Examiner then states that, "No attempt has been [fol. 3613] made to account for the seven months' delay intervening between the receipt of the last Office letter and Marconi's arrival in this country."

And the Examiner calls attention to *Ex Parte McElroy*, 101 O. G., 2823.

Deponent does not believe that this case is applicable to the present case, because in the McElroy case it appeared

that it had been "the practice" of the applicant to postpone the amending of his applications until the last few weeks before the time limit expired, and that when in this instance he was about to amend his application he was stricken with typhoid fever, and therefore could not do so, and *by reason of this practice* the Commissioner held that the first eleven months delay was "intentional," and therefore that the delay was unavoidable because only a "certain portion of the delay" had been explained away.

This "*practi* " of waiting eleven months before making an amendment has not been adopted or llowed by this applicant, as I will now point out.

The application was filed November 7th, 1900. It was rejected December 24th. It was amended July 1, 1901. It was again rejected August 12, 1901. Again it was amended on December 6, 1901. Amended April 28, 1902, and again rejected on June 3, 1902.

The last amendment was filed six weeks after rejection.

Considering the fact that the applicant resides more than [fol. 3614] 3000 miles away from his attorneys, it necessitates consultation with him by letters back and forth, often several letters to prepare a single amendment.

If, however, it is thought that it is necessary to explain the reason for not acting on this case between the 3rd day of June, 1902, and the 27th day of January, 1903, deponent, upon information and belief, states as follows; basing his information upon communication, from the Marconi Company, and upon statements in the public prints as to the movements of Mr. Marconi.

Mr. Marconi was not, unless for very brief periods of time, in a position to take up the amendment of his application and could not be visited by his attorneys.

In the early part of July, 1902, Mr. Marconi was called to Italy to make experiments in wireless telegraphy for the Italian Government upon the Italian war-ship "Carlo Alberto," which had been furnished to him by the Italian Government for this purpose. He left London, as I am informed, very hurriedly for this purpose, sailing first to Gibraltar and afterwards to Spezzia.

During this time, he succeeded, as I was informed, in transmitting messages, by his wireless system, between England and Gibraltar, and subsequently successfully transmitted one or more wireless messages from England direct to Spezzia, in the gulf of Genoa. This latter achievement

was considered, at the time, a marvelous event, as it involved transmission across Europe. These experiments occupied, [fol. 3615] as I believe, a number of weeks, and after completing the same, he was invited by the Czar of Russia to come to Cronstadt, Russia, and was permitted by the Italian Government to go there upon the same war-ship, "Carlo Alberto." He accordingly sailed for Russia, and during this trip was successful in transmitting messages from England to Cronstadt. For this achievement, as I was informed, he was decorated at the time, by the Czar of Russia, with an Order.

We were informed that it was hoped that he would return to England in September, 1902, and that he would then proceed immediately to Cape Breton, Canada, but he was unable to do so. It was always, however, represented to us that he was coming to this country soon. He did not arrive, however, in Cape Breton, until December, 1902, and during all of the time from June to December was only temporarily in England, as we were informed. That Mr. Marconi came to this country as early as feasible is, we think, sufficiently indicated by the fact that he came on the "Carlo Alberto," which had been placed at his service for the purpose, and he was, naturally, anxious not to keep that ship longer than absolutely necessary, she being under orders to sail for Venezuela as soon as she could be spared from his experiments.

It thus appears that from June 3, 1902, until Mr. Marconi arrived in Canada, he was more than 3000 miles away from his attorneys, being for the most part of the time in the Mediterranean and Baltic Seas, conducting experiments on the above mentioned Italian war-ship, and therefore it is [fol. 3616] submitted to your Honor that the first part of the delay has been satisfactorily shown to have been unavoidable, as well as that of the last part of the whole period.

The Examiner states that "it would seem that some action, based on the partial information obtained from Marconi January 27, 1903, might have been submitted by the attorneys between May 13th and June 3, 1903, that would have saved the case from abandonment." We can hardly suppose that the Examiner recommends or approves of the practice of making a merely formal and insufficient reply to an Office letter, and one known to be insufficient at the time of making it, especially when, as in this case, detailed and accurate information on which to base what

was believed to be an adequate reply, was promised in a short time.

The only information which Mr. Marconi gave us on January 27, 1903, was a very brief verbal one, and as Mr. Marconi informed us that upon his return to England he would send us a full written report, after he had consulted with his documents there, we had no records to go by to formulate an amendment between May 13, 1903, and June 3, 1903, as suggested by the Examiner. The verbal information which Mr. Marconi did give us on January 27, 1903, was not sufficiently clear or well enough understood by us to have answered the last Office action.

It is submitted that Mr. Marconi's attorneys, in view of [fol. 3617] the facts above set forth, and in view of the facts set forth in my former affidavit, had every reason to expect that they would have received, long before the year's time elapsed, sufficient information from Mr. Marconi to amend the case in response to the last Office letter, and that the delay in the case arose from the exceptional circumstances of Mr. Marconi's absence from England, engaged in experiments in perfecting his wireless system, and the inevitable and unexpected delays in coming to this country, and in putting his attorneys in possession of his statements which grew out of those exceptional occupations.

L. F. H. BETTS.

Sworn to before me this 22nd day of October, 1903.

JAMES J. COSGROVE,

(NOTARIAL SEAL). *Notary Public, New York County.*

[fol. 3618] UNITED STATES PATENT OFFICE.

Room 91.

In the matter of the Application of Guglielmo Marconi, for Patent for Apparatus for Wireless Telegraphy, Serial No. 36,010. Filed November 10th, 1900.

New York, October 24, 1903.

Hon. Commissioner of Patents, Washington, D. C.

SIR:

We transmit herewith a supplemental showing, duly verified, in the matter of the petition to revive the above entitled application.

In order to remove any portions of the amendment of October 6th, 1903, (filed with the original showing and petition) which may be considered objectionable on the ground that said amendment cannot be entered because, in the Examiner's opinion, it contains new matter and also contains method as well as apparatus claims, it is hereby requested that the following amendment may be made to the aforesaid amendment of October 6th, 1903.

Cancel the last eleven lines of page 1 of the amendment dated October 6th, 1903.

[fol. 3619] Cancel the first eight lines of page 2 of said amendment.

Cancel claims 21 and 22 on page 9 of said amendment.

Cancel the second paragraph on page 10 of said amendment, said paragraph reading as follows:

"A new Figure (Fig. 9) has been added to the drawings."

Respectfully submitted,

BETTS, BETTS, SHEFFIELD & BETTS,
Attorneys for Marconi.

[fol. 3620] Paper No. 12

U. S. Patent Office, Oct. 26, 1903, Mailed

Department of the Interior, United States Patent Office

Washington, D. C., October 26, 1903.

In the matter of the application of Guglielmo Marconi, for patent for Apparatus for Wireless Telegraphy. Filed November 10, 1900. Ser. No. 36,910.

Before the Commissioner by Petition

Examiner's Statement

On October 12, 1903, a petition was filed to revive the above entitled application, which became abandoned June 3, 1903, under R. S. 4894; on October 15, 1903, the Examiner submitted an answer recommending that the petition be denied; and on October 24, 1903, an additional affidavit was filed in support of the petition of October 12th. In view of this affidavit the following answer is respectfully submitted.

The additional affidavit sets up an argument and a statement of alleged facts, based on the information and belief

of one of the attorneys, as to Marconi's movements between June 3, 1902, and the latter part of December, 1902, said facts, so alleged on information and belief, being intended to show that the delay existing between the aforesaid dates was an unavoidable delay.

The facts submitted in this additional affidavit, in the Examiner's opinion, merely serve to emphasize the position [fol. 3621] taken by him in his answer of October 15th, namely, that Marconi was unable to attend to his Patent Office business by reason of other business interests.

What Marconi's other business interests were is immaterial and the fact that he was successful in his business, as repeatedly emphasized by the attorney in both original and supplemental showings evidently for the purpose of strengthening his case, is irrelevant and incompetent.

It was held in ex parte Smith, 101 O. G., 1369, that the plea of "other business engagements" was not sufficient to account for the delay which resulted in the abandonment of an application under R. S. 4894.

In ex parte Beecher, 101 O. G., 1132, "unavoidable delay" was defined as meaning "circumstances beyond the control of the applicant".

From the spirit of these adjudications it would seem that Marconi's successes should not be given such consideration as would make up for the deficiencies in a showing of unavoidable delay. If Marconi had failed to transmit messages from Poldhu to Spezzia and had not been honored by the Czar of Russia, the showing submitted by the attorney would be entitled to just as much consideration.

It seems that ex parte McElroy, 101 O. G., 2823, cited in the Examiner's answer of October 15th as authority for holding that a showing of unavoidable delay must cover the entire period, has been objected to by the attorney as not on all fours with the present case. Attention is, therefore, respectfully called to the following decisions of the Commissioner of Patents, which show that the uniform and [fol. 3622] settled practice of the office under Rule 72 has been to require "a showing of facts covering the entire period" in order to warrant the revival of an abandoned application:

Ex parte Root, 40 O. G., 811.
Ex parte Fenno, 52 O. G., 1665.
Ex parte Edison, 56 O. G., 1061.

Ex parte Murray, 56 O. G., 1060.
Ex parte Clarke, 61 O. G., 286.
Ex parte Heine, 64 O. G., 1006.
Ex parte Warren, 96 O. G., 2410.

It has been maintained that this case should be revived because Marconi's British patent No. 7777 of 1900, will bar the filing of a new application for the subject matter disclosed in this case. Not only said British patent but also Belgian patent No. 152,840 and French patent, No. 308,204, and it is believed other foreign patents for the same invention, will bar such new application, and this very fact furnishes additional reason why the application should not have been permitted to become abandoned,—ex parte Pietzner, 103 O. G., 2171.

The proposed amendment submitted with the supplemental affidavit of October 24, 1903, removes the objection to the proposed amendment of October 12, 1903, in that it cancels therefrom the method claims and the new matter referred to in the Examiner's answer of October 15, 1903, but the amendment of October 12th as amended is not such as would put this case in condition for allowance.

No reason is seen for favorably recommending this petition.

Very respectfully,

WM. A. KINNAN,
Actg. Examiner, Division XVI.

G.K.W.

[fol. 3622] Serial No. 36010.

Paper #13

Filed Nov. 4, 1903

Docket Clerk, Nov. 4, 1903, U. S. Patent Office

United States Patent Office

In the Matter of the Application of GUGLIELMO MARCONI for a Patent for Apparatus for Wireless Telegraphy; Filed November 10, 1900; Serial No. 36,010

Before the Commissioner, by Petition

Brief on Behalf of Marconi

This is a petition filed by the Attorneys for Marconi, that this Application be revived as a pending Application.

under the provisions of the Statutes of the United States.

On October 12, 1902, this petition was filed, and on October 15th the Examiner submitted an answer, recommending that the petition be denied. Thereupon, under date of October 24th, we submitted an additional affidavit, in the nature of a supplemental affidavit, and under date of October 26th, the Examiner has held that "no reason is seen for favorably recommending this petition."

The one-year time limit provided by the statute expired on June 3, 1903.

In the petition as filed on October 12th, it was shown that Marconi did not arrive in the United States from abroad, [fol. 3624] until the 27th day of January, 1903. The petition supported by a duly verified affidavit, explains in detail the several attempts, beginning on the day he arrived, January 27th, 1903, which the attorneys made to secure sufficient information from him about this highly technical invention, to completely and satisfactorily answer the last office action of June 3, 1903.

It was shown that not only was one attempt made, but several attempts were made between January, 1903, and June of the same year, although Marconi was not in this country at any time between those dates, except from the 27th to the 31st of January, 1903. It is further shown that when this application was called to his attention in January, 1903, Marconi stated that he was unable to fully and completely answer this office letter until he had consulted some documents which were then in England.

In view of the many attempts made to secure information to amend this case between January and June, 1903, it is satisfactorily explained why the amendment was not filed during this period, and therefore the Examiner's statement of October 15th makes no criticism as to the sufficiency of the excuse for non-action after January, 1903, except that the Examiner suggests that "some action on the partial information obtained from Marconi on January 27, 1903, might have been submitted by the attorneys between May 13th and June 3, 1903, that would have saved the case from abandonment.

[fol. 3625] We can hardly suppose that the Examiner recommends or approves of the practice of making a piecemeal reply to an Office letter, and one known to be in the nature of a piecemeal reply, and insufficient at the time of

making it, especially when, as in this case, detailed and accurate information on which to base what was believed to be an adequate reply, was promised in a short time.

The only information which Mr. Marconi gave us on January 27, 1903, was a very brief verbal one, and as Mr. Marconi informed us that upon his return to England he would send us a full written report, after he had consulted with his documents there, we had no records to go by to formulate an amendment between May 13, 1903, and June 3, 1903, as suggested by the Examiner. The verbal information which Mr. Marconi *did* give us on January 27, 1903, was not sufficiently clear or well enough understood by us to have answered the last Office action.

The Examiner, in his letter of October 26th, practically admits that the delay from January to June of 1903 was "unavoidable".

But the Examiner, in his letter of October 5th, recommends that "the petition be denied", because it had not *then* been shown that the delay in filing the amendment from June of 1902, to January of 1903, was "unavoidable" [fol. 3626] on the authority of ex parte McElroy, 101 O. G. 2823.

We therefore filed a supplemental showing as to where Mr. Marconi was during the period between June of 1902 and January of 1903, when he first arrived in this country, although we did not believe, and do not believe now, that the decision in the McElroy case is applicable to the present case.

This supplemental showing is contained in an affidavit, duly verified under date of October 22*th*.

It shows that Marconi was not in the United States from the time of the last office action, June 3, 1902, until January of 1903.

Marconi was, therefore, unavailable for consultation.

It was further shown that early in July, 1902, Mr. Marconi left England, where the present owners of this Marconi application reside, and went to Italy, where he was engaged in conducting important experiments upon the Italian war-ship "Carlo Alberto," which had been loaned him by the Italian Government for that purpose. It was further shown that these experiments lasted for several weeks in the Mediterranean Sea, upon this war-ship, and that thereafter, Mr. Marconi sailed up the Baltic Sea upon this same

war-ship to Cronstadt, Russia, still continuing his experiments, which lasted sometime in addition.

The Examiner, in his letter of October 26th, has criticised [fol. 3627] this showing as to Marconi's movements during this period, as immaterial and irrelevant, because the Examiner claims that "Marconi was unable to attend to his patent office business by reason of his other business interests."

It is submitted that this showing is both material and relevant. It is material and relevant because it explains where Mr. Marconi was during the Summer and early Autumn of 1902, and shows that Mr. Marconi was more than 3000 miles away from his attorneys, and also shows that he was many hundreds of miles away from the owners of his patent. He was, therefore, unavailable during this period for consultation.

It is also shown in the supplemental affidavit that Mr. Marconi was expected by his attorneys to come to the United States early in the Fall of 1902, but that he was delayed from time to time by this important business, and that he only returned to England for a very short time after completing his experiments on the "Carlo Alberto" in the Baltic Sea, and then sailed for Canada upon the same Italian war-ship, which was still being loaned him by the Italian Government to continue his experiments while crossing the Atlantic, and that he arrived on this war-ship in Canada about December of 1902.

While, therefore, Mr. Marconi was on this war-ship conducting his experiments in the Mediterranean Sea, the Baltic Sea, and the Atlantic Ocean, it is only fair to say that he was "unavoidably" prevented from taking action. [fol. 3628] It is submitted, therefore, that not only has it been shown that the delay from January to June, of 1903, was "unavoidable," but also that the delay from June, 1902, until January of 1903, was also "unavoidable".

The Examiner practically claims that during this first period of the year's time, Mr. Marconi should have given up conducting his experiments for the Italian Government, on the "Carlo Alberto," for the purpose of attending to his Patent Office business.

This is what the Examiner's contention amounts to.

It is not believed that this is sound.

While it may be true that where an inventor resides in the vicinity or near his attorneys and is engaged in *ordinary*

mercantile business, that an excuse of "other business engagements" as a reason for not attending to his Patent Office matter, is not a good excuse, yet where, as in the present case, it is shown that the inventor resides more than 3000 miles away from his attorneys and that during the period of time in question he was conducting experiments for the Italian Government, a different and more reasonable view of the facts should be taken. The rule certainly does not contemplate any obligation by the applicant to travel hundreds of miles during the first part of the period for action and come from foreign countries when there was every reasonable expectation, and a continuing expectation, that his business abroad would allow him ample time after it was finished to take the required action.

We submit that the decisions which the Examiner cites in his letter of October 26th do not apply to this case.

[fol. 3629] In ex parte McElroy, 101 O. G. 2823, it was held that the delay was not "unavoidable" because it had been shown that it was the "*practice*" of the applicant to *only* amend his applications within the last week or two of the time limit, and that in this case he was unable to do so because he had been stricken during this last week or two with typhoid fever. The Commissioner therefore held that the delay was "intentional."

The McElroy case does not apply to the present case. First, because it is shown that it has not been the "practice" of this applicant to amend his applications only within the last week or two of the time limit (the last amendment having been made about two months after official action); and second, because it has been shown that the attorneys made repeated efforts to obtain sufficient knowledge to amend this case during the whole last six months of the time limit, the first being made five months before the year's time expired.

In ex parte Root, 40 O. G. 811, it appeared that only twelve days before the time limit had elapsed, the attorneys made a *single* effort to have this case amended, which was unsuccessful. This effort consisted in writing a letter to another lawyer in Washington. The Commissioner said:

"The writing of this note and its failure to come into Mr. M. F. Halleck's hands at an earlier date, constitute the *sole* reason presented to bring the case within the statute for reinstatement of applications abandoned for want of prosecution * * * It is therefore a case in which the

entire period of two years is allowed to expire without any attempt at definite action." (Italics ours).

This case is no precedent, therefore, for the Marconi case: first, because the engagements and absence from home were exceptional and because here the attorneys made not one, but several attempts; and second, because these attempts were not made during the last week or two of the time limit [fol. 3630] but at least as early as five or six months before the time limit expired.

Ex parte Fenno, 52 O. G. 665 was a case following the decision in ex parte Root, and the only showing in this case was that during the last *month* of the time limit, the applicant was in such a bad financial condition that he was unable to pay for an amendment being filed. The Commissioner says:

"It is true that he states that in April, 1890, he was short of money and had hard work to get what he needed; but there is no showing as to what his financial condition was during the preceding twenty-three months. Ex parte Root, C. D. 1887, 81."

Here again was a case where no effort was made until the time limit was about to expire and then the showing was that only a single effort was made.

Such is not the situation, as we have pointed out, in the present instance.

Ex parte Edison, 56 O. G. 1061, likewise follows ex parte Root, since the only showing in the Edison case was that during the time limit the attorney once wrote to the Patent Office for a copy of a previous action and the Commissioner held that this letter of Edison's attorney was not an "action" as required by the statutes.

Ex parte Murray also follows ex parte Root. In the Murray case it did not appear that the attorneys had *ever* attempted during the two years' period to amend the case or to get sufficient information from the applicant to amend the case.

[fol. 3631] Such is not the situation in the case at hand.

In ex parte Clarke, 61 O. G. 286, the petition was denied because "the delay has been more than *four* years, and applicant only accounted for one." Furthermore, it did not appear that even during this one year, either applicant or the attorney had endeavored to amend the case or secure

such information as would have enabled the attorney to amend the case.

Ex parte Heine, 64 O. G. 1006, merely follows ex parte Root, which we have shown is clearly distinguishable from the present case.

Ex parte Warren, 96 O. G. 2410, was another case where the applicant's attorneys waited until within a week or two of the time limit before filing a proper amendment or took an appeal. The Commissioner states:

"By *intentionally* postponing proper action until the last of the time allowed, the attorneys assumed the risk of accidents, mistakes, or other circumstances which might then prevent action." (Italics ours)

It is shown in the Marconi case that the attorneys did *not* wait until the last of the time limit, but at least five months prior to that time endeavored to get from the inventor such information as would enable them to properly amend the case, but that the inventor was unable to give this information, and that during the succeeding five months not one, but several additional attempts were made to secure this information."

[fol. 3632] We have shown, therefore, that not one of the cases cited by the Examiner is applicable to the case at bar.

We have further shown that not only was the delay during the last six months of the year "*unavoidable*," but that the delay during the first six months as well, was "*unavoidable*."

Apparently, the supplemental showing which we have made has somewhat altered the Examiner's opinion as to the equities of this case, because in his first letter of October 15th, he recommended that the "petition be denied," while in his letter of October 26th, the Examiner merely states that "no reason is seen for favorably recommending this petition."

It is respectfully submitted, therefore, that in view of the detailed showing now presented in this case as to the efforts made to amend the case, and as to the whereabouts of the inventor, Marconi, during the whole period of the year's time, that the petition to revive this application should be granted.

Respectfully submitted,

BETTS, BETTS, SHEFFIELD & BETTS,

Attorneys for Marconi.

New York, October 30, 1902.

[fol. 3633] Serial No. 36,010, Paper No. 14. Notice of Commr's Decision. Dated 190.

E. E. G.

Department of the Interior,
United States Patent Office

Washington, D. C., December 3, 1903.

In the Matter of the Application of GUGLIELMO MARCONI. Apparatus for Wireless Telegraphy. Filed Nov. 10, 1900. Serial No. 36,010.

Petition That Applicant be Held Not to be Abandoned.

SIR:

You are hereby informed that the above petition has been denied by the Commissioner. Please find enclosed herewith a copy of the decision.

By direction of the Commissioner:

Very respectfully,

C. M. IRELAN,
Chief Clerk.

F.

Guglielmo Marconi,
c/o Thos. E. Robertson,
605 Seventh St.,
Washington, D. C.

[fol. 3634] M. H.

Serial No. 36,010. Paper No. 14.

Commr's Decision.

Recorded Vol. 78, page 119.

United States Patent Office.

Ex parte GUGLIELMO MARCONI.

Apparatus for Wireless Telegraphy.

Petition.

Application filed November 10, 1900, No. 36,010.

Messrs. Betts, Betts, Sheffield & Betts and Mr. T. E. Robertson for applicant.

This is a petition for a ruling that the above-entitled application is not abandoned, notwithstanding the fact that no action was taken in prosecution thereof for more than one year. It is contended that the delay in prosecution was unavoidable.

The last office action was dated June 3, 1902, and no reply was received until this petition was filed on October 12, 1903.

The facts relied upon as showing that the delay was unavoidable are set forth in two affidavits by one of the attorneys. It is said that the examiner's letter raised certain technical questions, which Marconi himself could best answer and that:

"it was decided to await his arrival in this country before submitting the questions raised by the examiner's letter to him."

It is said further that Marconi did not, in fact, come to this country until January 27, 1903, at which time the papers in the case were submitted to him and he then gave the at- [fol. 3635] torneys some information but not enough to enable them to make a completely responsive action in the case. It is said that Marconi found it necessary to consult certain records in London before he could furnish all of the

information necessary. Marconi then left this country for Europe, and thereafter the attorneys wrote two letters to his company asking for information and the papers. On April 11, 1903, they received a letter from the company saying that the "affidavits" had been despatched, but they were never received. Two more letters were written to the company, and on July 3rd a cablegram was received, saying that Marconi was ill and that the papers could not be forwarded at once. On August 21st the papers were received, but were accompanied by no remarks or explanation by Marconi. Marconi was in New York from September 28th to October 3rd, and the information desired was then available.

This showing attempts to excuse the failure of the attorneys to act by the statement that it was necessary to consult the inventor, but no effort whatever was made to consult the inventor for seven months after the office action. He was consulted in January, 1903, however, and assuming that he was the one then called upon to act, there is no satisfactory explanation why he did not furnish the information desired. The suggestion is made that he was very busy upon other matters which he seems to have regarded as more important, but this is not a sufficient excuse for inaction. It does not appear that he was any more busy then than at any other time. It appears merely that he was a busy man, and by choice devoted his attention to other matters instead of this. The cablegram as to Marconi's illness was after the application was abandoned, and there [fol. 3636] fore it does not appear that the illness had anything to do with the failure to act within the year.

After the examiner had answered this petition, the attorney presented a supplemental affidavit, attempting to explain the inaction for the first seven months of the year fixed by law for action. It was there said:

"Mr. Marconi was not, unless for very brief periods of time, in a position to take up the amendment of his application and could not be visited by his attorneys."

It is said that in July, 1902, Marconi went to Italy, and a few weeks later to Russia, and expected to return to England and then go to Canada in September, 1902. He did not, in fact, reach Canada until December, 1902, and ar

rived in this country on January 27, 1903. The attorneys were awaiting his arrival in this country, and say:

"It was always, however, represented to us that he was coming to this country soon."

The movements of Marconi before coming to this country might be pertinent if they were what prevented the attorneys from communicating with him, but that does not appear to have been the case. No effort seems to have been made to communicate with him. It seems clear that the consultation might have been conducted by correspondence and that in fact seems to have been the intention after the interview of January 27, 1903.

The year allowed by law for action is ample, and it is only under very exceptional circumstances that a delay for a longer period is justified. The mere plea that the inventor was busy upon other matters and did not have time to devote to the case under consideration, cannot be accepted as a showing that the delay for such a long time was unavoid- [fol. 3657] able. The word "unavoidable" in the statute means more than that to act would have been inconvenient.

Since the delay in this case is attempted to be explained on the ground that Marconi did not furnish the necessary information, it cannot be held that the delay was unavoidable, in the absence of a showing by him of good reasons why he did not furnish the information.

The petition is denied.

F. I. ALLEN,
Commissioner.

December 2, 1903.

[fol. 3638] Serial No. 36010

Paper No. 15

Request for Rehearing

aff.

Filed February 24, 1904

Docket Clerk, Feb. 24, 1904. U. S. Patent Office.

United States Patent Office

In the Matter of the Application of Guglielmo Marconi, for Patent for Apparatus for Wireless Telegraphy, Serial No. 36,010. Filed November 10, 1900.

New York, February 19, 1904.

Hon. Commissioner of Patents,
Washington, D. C.

Sir:

This Application was rejected on the 3rd day of June, 1902. On the 12th day of October, 1903, petition was filed asking that the Application be declared a pending Application under the authority vested in your Honor, by the provision of Section 4894 of the Revised Statutes.

On December 2, 1903, this petition was denied, in the absence of a verified showing by Marconi himself.

We respectfully ask for a re-consideration of the foregoing petition in view of the supplemental showing contained in the affidavits of Guglielmo Marconi, L. F. H. Betts and T. E. Robertson, filed herewith.

Respectfully submitted,

BETTS, BETTS, SHEFFIELD & BETTS,
Attorneys for Applicant.

[fol. 3639] In the United States Patent Office

In Reapplication of Guglielmo Marconi, Serial No. 36,010. Filed November 10, 1900. Apparatus for Wireless Telegraphy.

London, England, ss:

Guglielmo Marconi, being duly sworn, deposed and says:

I am the applicant in application for United States Letters Patent Serial No. 36,010, filed November 10, 1900, for apparatus for wireless telegraphy.

In the latter part of the year 1901, and early in the year 1902, I was in America, and at that time succeeded in transmitting signals from Poldhu in Cornwall, to St. John's, Newfoundland by my system of wireless telegraphy, and satisfied myself that it was possible to transmit messages on a commercial scale. Early in 1902 I was, however, compelled to return to England, but it was my intention to return to America as soon as possible for the purpose of installing a station for the commercial transmission of signals across the Atlantic Ocean, which station was to be installed at Cape Breton, Nova Scotia to connect with our station at Poldhu, Cornwall, on the one hand, and with a station at Cape Cod, U. S. A., on the other hand. As time went on, it became more and more important to the interests of my various companies, that this long distance transmission station should be established, and I was con- [fol. 3640] stantly urged to return to America for this and other purposes connected with my interests in America, and particularly in the United States. I was constantly expecting to make this trip to America, but it became necessary to postpone my departure from time to time.

In June, 1902, an opportunity presented itself to obtain the use of the "Carlo Alberto", a ship of the Italian Navy, for the purpose of carrying out tests of my system, and I determined to make use of this opportunity to make tests of long distance transmission over land and sea. Accordingly and on the 18th day of June, 1902, I commenced my experiments on the "Carlo Alberto" round the Coast of England, which were continued uninterruptedly between this ship and a number of my stations, i. e. Poldhu, The Lizard, Poole, Niton, etc., until the 6th July.

On the 6th July I left Dover on the "Carlo Alberto" for Cronstadt, carrying out experiments during the entire voyage, and on 22nd July I sailed from Cronstadt to England, where I arrived on August 1st. All the time from August 1st to the 24th I was busily engaged in experiments preparatory to another voyage on the "Carlo Alberto". It had been my intention to sail from there to America, for the purpose of installing the long distance transmission station there, but decided to return first to the Mediterranean, and on August 25th, 1902, I sailed from England for the Mediterranean on the "Carlo Alberto", with the intention of returning to England about the first week in September, and of proceeding from there to Cape Breton, and after establishing communication between Cape Breton and Poldhu, to proceed to Cape Cod, U. S. A.

I am informed and believe that my representatives in [fol. 3641] America were notified of this change of plans. During all of the time that I was carrying on these tests on the "Carlo Alberto", I was steaming from place to place, and often, on account of the uncertainty of my movements, it was impossible for correspondence to reach me.

These experiments in the Mediterranean occupied my time until the 20th day of September when I returned to England, and on the 20th day of October, 1902, I sailed from England for Cape Breton, arriving there on the 31st day of October, 1902. From that time on, I was constantly expecting to leave Cape Breton, for New York City, and I am informed and believed that certain important matters which demanded my attention in New York, were postponed from time to time, pending my arrival. The experiments at Cape Breton occupied a longer time than I had anticipated, and I did not leave there for New York until the 14th day of January, 1903. In the meantime I received at Cape Breton a letter from my attorneys, Messrs. Betts, Betts, Sheffield & Betts, bearing date of January 3rd, 1903, asking for certain information which they desired in regard to my application serial No. 36,010, for the purpose of making an amendment in that application, and of overcoming the objections urged thereto by the Examiner in the United States Patent Office. On January 10, 1903, I telegraphed to Messrs. Betts, Betts, Sheffield & Betts, to send me copies of the papers in this case, and under date of January 10th they mailed these copies to me, and they were duly received at Cape Breton.

On examining these papers, I discovered that I would be unable to answer the questions presented by the Action of the Patent Office, dated June 3rd, 1902, without resort to my papers stored in London, and for this reason I postponed any report on this application until I should arrive in New York City.

[fol. 3642] I arrived in New York City about January 23, 1903, and remained there several days, during which time I consulted with my attorneys, Messrs. Betts, Betts, Sheffield & Betts, and I discussed with Mr. L. F H. Betts, of that firm, this application serial No. 36,010, and I promised to send to him the information which was necessary, upon my return to London, and upon my examination of the papers stored there. At this time I requested Mr. Betts to write a letter to me, in London setting forth exactly the papers and information which were necessary in connection with this application, in order that I might prepare such papers in London. Upon my arrival in London, it became absolutely necessary for me to give my attention to pressing matters in connection with the development of my inventions in wireless telegraphy. Mr. Betts had written the letter which I had asked for, under date of January 27, 1903, and I took advantage of the first opportunity to prepare the papers asked for in that letter, and prior to April 4, 1903, I prepared and despatched to Messrs. Betts, Betts, Sheffield & Betts, the necessary papers. These papers were left in the hands of the Notary to be sent to Messrs. Betts, Betts, Sheffield & Betts, about the end of March or the beginning of April 1903. On April 4, 1903, I received a telegram from the Marconi Wireless Telegraph Company, Limited, of London, asking me if the papers in this case had been prepared and sent, and I informed Marconi's Wireless Telegraph Company, Limited, that these papers had been sent, and I am informed and believe that this information was imparted to Messrs. Betts, Betts, Sheffield & Betts, by that Company.

On the 22nd day of May 1903, a letter was received, bearing date May 13, 1903, from Messrs. Betts, Betts, Sheffield & Betts, by Marconi's Wireless Telegraph Company, Limited, [fol. 3643] of London, stating that these papers had never been received and asking that they be sent to them immediately. At that time I was in Italy, at Pisa, where I had been ordered by Dr. Mazzoni, of Rome, for a recupera-

tive rest, in order that I might recover from an illness from which I had suffered since about April 20th. At this time I was unable to attend to any business matters whatever. On my return to England, in May, 1903, I had not recovered from my previous illness, and was, by doctor's orders, again confined to bed for a week or ten days. In fact, during the two months from about the middle of April to about the middle of June, 1903, I was not only incapacitated by illness, from attending to patent business, but was, much to my own inconvenience and that of my companies prevented from attending to many other urgent matters of business.

As soon as I was able to attend to this matter, and in the month of August, 1903, I forwarded to Messrs. Betts, Betts, Sheffield & Betts, papers which I believed would be sufficient to meet their requirements. Thereafter, I arrived in New York City, on September 28, 1903, and remained there until October 3, 1903, and at this time the full information was given to Messrs. Betts, Betts, Sheffield & Betts, and I am informed and believe that the necessary amendment was immediately filed by them.

GUGLIELMO MARCONI.

February, 1904.

[SEAL.]

G. F. WARREN,
Notary Public.

[NOTARIAL SEAL.]

(Foreign Revenue Stamps.)

[fol. 3644] Consulate-General of the United States of America for Great Britain & Ireland at London

I, Richard Westacott Acting Consul-General of the United States of America at London, England do hereby make known and certify to all whom it may concern that George Frederick Warren who hath signed the annexed Certificate, is a Notary Public, duly admitted and sworn and practising in the city of London, aforesaid, and that to all facts by him so done full faith and credit are and ought to be given in Judicature and thereout.

In Testimony Whereof, I have hereunto set my hand and affixed my Seal of Office at London aforesaid, this Third day of February in the year of our Lord One Thousand Nine Hundred and Four.

[SEAL.]

RICHARD WESTACOTT,
Acting Consul-General.

[CONSULAR SEAL.]

[fol. 3645] United States Patent Office

In re Application of Guglielmo Marconi No. 36,010. Filed Nov. 10, 1900. Apparatus for Wireless Telegraphy

STATE OF NEW YORK,
County of New York, ss:

Louis Frederick Holbrook Betts, being duly sworn, deposes and says:

I am a member of the firm of Betts, Betts, Sheffield & Betts, attorneys for Guglielmo Marconi in the above-entitled application.

When I received the Office action bearing date of June 3, 1902, in the above-entitled application, I had been informed and believed that it was Mr. Marconi's intention to come to America for the purpose of establishing a long-distance transmission station at Cape Breton, Nova Scotia, and also for the purpose of establishing a station at Cape Cod, Massachusetts, and I was aware that he was being urged to come to America for this purpose, at the earliest possible moment, since it was of considerable importance to the interests of the Marconi Wireless Telegraph Company of America that this long-distance station should be installed. I was also aware that Mr. Marconi intended to visit New York at the time of his contemplated trip to this country, and that there were many matters awaiting [fol. 3646] his consideration in New York, and I believed that Mr. Marconi was likely to leave England for this country at any time. During the early part of July, 1902, it came to my knowledge that Mr. Marconi had left England for Cronstadt, Russia, for the purpose of carrying out certain experiments on the "Carlo Alberto", in the Baltic Sea, a ship belonging to the Italian Navy, and loaned to Mr.

Marconi by the Italian Government. It was expected in America that as soon as Mr. Marconi completed his experiments he would sail for America for the purpose of establishing a long-distance transmission station.

On the 21st day of August, 1902, a letter was addressed to this office by Mr. H. Cuthbert-Hall, Managing Director of Marconi's Wireless Telegraph Company, Ltd., of London, which letter was duly received, and with this letter was received a copy of a letter bearing date of August 16, 1902, addressed to the Marconi Wireless Telegraph Company of America, which letter contained the following information:

"You may possibly have learned from announcements in the press that Mr. Marconi is going to the Mediterranean next week on the 'Carlo Alberto', and will probably take the opportunity of making further experiments with the Poldhu Station over land and sea combined.

"We have thought that you might be surprised that any engagement should now be entered into which tends further to postpone the proposed trans-Atlantic transmission. This engagement has, however, been entered into in the interests not only of this Company, but of all the Marconi Companies. * * *

"* * * It is hoped that he" (Mr. Marconi) "will return to England about the first week in September; he will then proceed to Cape Breton, and after communication has been established between that Station and Poldhu, he will then go on to Cape Cod and start the service there".

This letter, though it informed me that Mr. Marconi [fol. 3647] would not be in this country so early as I had expected, led me to believe that he would be available for a personal interview not later than the 1st of October, 1902, and it also informed me that he would be, in the meantime, traveling from place to place on the "Carlo Alberto," and I knew that it would be practically impossible to communicate with him, or to secure any technical information from him.

Mr. Marconi did not, in fact, complete these experiments on the "Carlo Alberto" and leave England for Cape Breton until the middle of October, but during all the time from the 1st of June until he actually sailed from England it was represented to us that he was about to come to this country, and we knew that he was steaming from place to

place on the "Carlo Alberto", and that it was well nigh impossible to communicate with him.

Mr. Marconi did not arrive at Cape Breton until about the 1st of November, 1902. I am informed and believe that the exact date was the 31st day of October, 1902. In my affidavit, executed the 22nd day of October, 1903, in support of the petition to revive this application, I stated that Mr. Marconi did not arrive in Cape Breton until December, 1902. This date should have been "until November, 1902", and the date December, 1902, was included in my prior affidavit by mistake.

My partner, Mr. Frederic H. Betts, was at this time a director in the Marconi Wireless Telegraph Company of America, of which Company Mr. Marconi was, and still is, also a director, and in order to show that our office was kept informed as to Mr. Marconi's movements, and that [fol. 3648] we had good reason to expect him in New York immediately, I will state that the regular meeting of the Board of Directors of the Marconi Wireless Telegraph Company of America was postponed on October 28, 1902, for a period of two weeks, in the expectation that Mr. Marconi would be in this country at the end of that time.

Under date of November 13, 1902, we received a letter as follows:

New York, November 13, 1902.

Frederic H. Betts, Esq.,
120 Broadway, City.

Dear Sir:

The regular meeting of the Board of Directors of Marconi Wireless Telegraph Company of America which was postponed on October 28th, 1902, for the further period of two weeks, or pending the arrival of Mr. Marconi, was not held November 11th, 1902, there being no quorum.

It is now desired that the Directors consent to a further postponement of the said meeting for three weeks, pending the arrival of Mr. Marconi in New York.

Yours respectfully,

MARCONI WIRELESS TELEGRAPH
COMPANY OF AMERICA,
By C. J. STEEDMAN,

Secretary and Treasurer."

Under date of November 28, 1902, we received a second letter, as follows:

"November 28, 1902.

Frederic H. Betts, Esq.,
120 Broadway, City.

Dear Sir:

By telegram dated November 23d, we are advised that Mr. Marconi will be detained at Glace Bay until about the 6th prox. Kindly signify on enclosed postal whether you prefer that the meeting of the Board of Directors be further adjourned until, say, December 9th, or indefinitely postponed to be held upon special call on Mr. Marconi's arrival here.

Yours very truly,
MARCONI WIRELESS TELEGRAPH CO. OF AMERICA,
By J. BOTTOMLEY,
Secretary."

The information contained in these letters was communicated to me, and being thus in almost weekly expectation of the arrival of Mr. Marconi in New York, and believing, [fol. 3649] as I did, that it was of the utmost important that the very technical questions presented by the Patent Office action of June 3, 1902, should be discussed at a personal interview with Mr. Marconi, because of his peculiar knowledge of the subject-matter involved, I did not, at this time, write to Mr. Marconi asking for this information. In fact, during the time from June, 1902 to January, 1903, it appeared that Mr. Marconi would be in New York City about as soon as it would be possible to communicate with him by letter, because, since he was abroad travelling on the "Carlo Alberto", I knew that letters to him would necessarily be very greatly delayed and would perhaps not reach him at all, and after he arrived at Cape Breton he expected to leave there at any moment.

However, in view of the repeated postponements of his departure from Cape Breton, I finally wrote to him there, under date of January 5, 1903, asking him for the desired information in regard to this Application No. 36,010, although we still had six months to amend the same. On

January 10, 1903, I received from him a telegraphic request for copies of the papers in this case, as follows:

"Glace Bay N. S. Jan. 10.

Mirage New York

Send set papers 36010 addressed to Cape Cod station.

Marconi."

These copies were sent to him the same day, with a letter reading as following:

"January 10, 1903.

Guglielmo Marconi, Esq.,
Cape Cod Station, Marconi's Wireless Tel. Co., Ltd.,
Cape Cod, Mass.

Dear Sir:

Your telegram of January 10th from Glace Bay, has been received.

In accordance therewith, we send to you herewith complete set of papers in the matter of your Application No. 36,010.

[fol. 3650] "Will you please let us have your views in relation to this case at your earliest convenience.

Yours very truly,

B., B., S. & B."

About the middle of January, Mr. Marconi finally left Cape Breton for Cape Cod, and arrived there, as I am informed and believe, on January 16th, and on January 23rd, he arrived in New York City. He remained here several days, and at that time discussed with me this application No. 36010, and informed me that he would not be able to furnish the desired information without consulting his papers stored in London. I accordingly reduced to writing a statement of the information and papers which we desired, in the form of a letter to Mr. Marconi, bearing date of January 27, 1903. This letter was dispatched to Mr. Marconi, on January 27, 1903.

Later, on March 20th, our firm wrote *both* to Mr. Marconi and to Marconi's Wireless Telegraph Company, Ltd., urging that the information referred to, together with the papers, be sent as soon as possible. These letters read as follows:

"Guglielmo Marconi, "March 20, 1903.
c/o Marconi's Wireless Tel. Co., Ltd.
18 Finch Lane, London, England.

DEAR SIR:

Referring to your United States Application, serial No. 36,010 (for tuning the circuits at both the transmitting and receiving stations), you will recollect that, when you were here, we called your attention to the fact that the Examiner had rejected your Claims on the Tesla United States Patents, on the ground that you used the Tesla form of oscillator in connection with your wireless telegraph system. At that interview, you gave us, offhand, some of the reasons which distinguish your apparatus from that of Tesla, and you were to send us more information on this point. Accordingly, we asked you in our letter of January 27, 1903 (see page 4), to give us a full explanation, in detail, of the radical difference between your system and Tesla's.

[fol. 3651] "We have not heard from you in connection with this matter, and should be pleased to receive your views at the earliest day. The Application should be hurried as much as possible, having remained pending in the Patent Office for two and a half years. Another reason why this matter should be disposed of now, is that the Patent Office Examiner has, in connection with Dr. Fleming's Application, raised the point that he also uses the Tesla oscillator. Dr. Fleming, of course, uses your form, and the same reasons given in connection with your Application No. 36,010, will also be pertinent in connection with the reply to be filed in Dr. Fleming's case.

"If unable to send the desired information now, will you kindly indicate when you hope to do so.

Yours very truly,

BETTS, BETTS, SHEFFIELD & BETTS.

W. H. B."

"March 20, 1903.

"Marconi's Wireless Telegraph Co., Ltd.
18 Finch Lane, London, England.

DEAR SIRS:

Referring to Mr. Marconi's Applications Nos. 36,010 and 82,856, for United States Patents, and which have been pending since November, 1900, and November, 1901, respectively, we wrote to Mr. Marconi under date of January 27, 1903 (see copy of letter enclosed), asking him to consider certain positions taken by the Examiner in the United States Patent Office, in reference to the second-named Ap-

plication, and to send us an affidavit by himself, and possibly one by Dr. Fleming, pointing out fully the theory of operation of the apparatus of said Application, and also distinguishing the oscillator employed by him from that described by Tesla in the United States Patent sent with our letter. We now enclose a copy of the said Tesla Patent.

"We have not heard from Mr. Marconi in response to our letter, and are very anxious that the matters referred to should have early attention. Will you please, therefore, ask Mr. Marconi, at his earliest convenience, to give our letter of January 27, 1903, his complete consideration, and to have his views, as well as those of Prof. Fleming, sent to us in the form of affidavits.

"There is need for haste in prosecuting both of said Applications, especially in the case of No. 82,856, in which we may be able to file certain claims, somewhat broadly covering the employment of a single aerial with a plurality of transmitting or receiving branches connected thereto, thus bringing on an Interference which will decide priority of invention as between Mr. Marconi and other claimants.

Kindly acknowledge receipt of this letter.

Yours truly,

BETTS, BETTS, SHEFFIELD & BETTS,

W. H. B."

[fol. 3652] These were the only letters we wrote to either of these parties on that date, and in reply we received, on or about April 11th, the following letter:

"London, 4th April, 1903.

Messrs. Betts, Betts, Sheffield & Betts,
120 Broadway, New York.

Dear Sirs:

In connection with your letter of March 20th I have this morning wired to Mr. Marconi who is at present at Poldhu, asking him if the affidavits sent with your letter of Jan. 27th had been attended to and returned. Mr. Marconi wires in reply "Yes affidavits despatched by Notary".

Yours faithfully,

MARCONI'S WIRELESS TELEGRAPH CO., LTD.,

HENRY W. ALLEN,

Secretary & Asst. Manager."

These papers or affidavits were never received by us.

After waiting a reasonable time for the receipt of these papers, which were necessary in connection with Application No. 36,010, we again wrote to Marconi's Wireless Telegraph Company, Ltd., on May 13, 1903, in which we said:

"May 13, 1903.

"Marconi's Wireless Telegraph Company, Ltd.,
18 Finch Lane, London, England.

GENTLEMEN:

Referring to our two letters to Mr. Marconi under date of March 20th, and to our letter to your Company of the same date, will you please let us know when we may expect to have the affidavits or statements by Mr. Marconi relative (1) to the differences between the Marconi system and the Tesla system, and (2) relative to the system which employs one aerial for the reception or transmission of several messages simultaneously.

"As we wrote you at that time, two of Mr. Marconi's United States Applications are being held up awaiting these affidavits or reports, and we are also delaying action in the matter of the two applications filed on behalf of Prof. Fleming.

Yours very truly,
BETTS, BETTS, SHEFFIELD & BETTS,
W. H. B."

[fol. 3653] And again, in a fourth letter, dated June 5, 1903, we wrote as follows:

"June 5, 1903.

Marconi's Wireless Telegraph Company, Limited,
18 Finch Lane, London, England.

DEAR SIRS:

Referring to our two letters dated March 20, 1903, to Mr. Marconi, and our letter of the same date to you, we have not received the affidavits, arguments or instructions referred to therein.

As we have already stated, the two applications of Mr. Marconi a[illegible] the two applications of Prof. Fleming, are

being held up until we receive the information requested in said letters.

Will you please have the answers to said letters forwarded to us as soon as possible?

Yours very truly,

BETTS, BETTS, SHEFFIELD & BETTS,
W. H. B."

In answer we received the following cablegram, dated July 3, 1903:

"July 3, 1903.

Mirage, New York.

"Affidavits Multiple Patents Delayed by Marconi's illness. Hope to send twentieth.

HALL".

Upon receipt of this information, that Mr. Marconi had been ill, we took immediate steps to prepare a petition to the Commissioner of Patents, asking that he declare that the case had not become abandoned, since we believed that the delay in the case was such a delay as the Commissioner would be warranted in declaring "unavoidable", under the provisions of section 4894 of the Revised Statutes.

On July 8th, this petition, accompanied by an affidavit executed by myself, was forwarded to our representative in Washington, Mr. Thomas E. Robertson, of No. 605 Seventh Street. In a letter of July 9th, Mr. Robertson stated that this petition must be accompanied by an amendment, since the Commissioner of Patents had declared that he had no power to grant such a petition unless it was accompanied by an amendment. It was impossible for us to prepare this amendment without the necessary information from Mr. [fol. 3654] Marconi, and we were therefore compelled to await the arrival of the necessary papers.

On August 29, 1903, we received certain papers, but no remarks from Mr. Marconi. These papers did not convey sufficient information to enable us to make a full and complete response to the Office action of June 3rd. We were aware that Mr. Marconi intended to be in New York sometime during the month of September, 1903. Mr. Marconi was first in New York from September 28th to October 3rd, and we then secured from him the desired information. We thereupon prepared an amendment and argument in

reply to the last Office action on this application, which amendment, with the argument relating thereto, covers fifteen large typewritten pages, and is completely responsive to the last Office action. This amendment was forwarded to Mr. Robertson, in Washington, on October 6, 1903, and on October 12th the amendment and petition were filed in the Patent Office.

On December 2, 1903, the Commissioner of Patents denied this petition, and a copy of his decision was received by us on December 3rd. On December 5th we forwarded to Marconi's Wireless Telegraph Company, Ltd., at London, a copy of this decision, together with a copy of the petition, affidavits and brief, and asking that they ascertain if Mr. Marconi could make a satisfactory showing to explain the delay on his part, which delay the Commissioner of Patents had, in his decision, remarked upon as fatal to the petition. In this letter to the Marconi Company we also asked for further instructions in regard to this case. Under [fol. 3655] date of December 30, 1903, Mr. Marconi wrote us in regard to this application, saying that he would prepare a statement showing that the papers which he sent us in April, 1903, were the papers which we desired for use in this application, and also showing that he was unable to attend to business on account of illness during a considerable portion of the Spring of 1903. This statement was forwarded to us under date of January 6, 1904, and was received by us in due course. On January 22nd we forwarded to Mr. Marconi a letter accompanied by a draft form of affidavit which we desired him to execute, and which was based on the information contained in his statement. This affidavit, duly executed, was received by us on the 15th day of February, 1904.

L. F. H. BETTS.

Subscribed and sworn to before me this 20th day of February 1904.

[SEAL.]

JAMES COSGROVE,
Notary Public,
New York Co.

[NOTARIAL SEAL.]

[fol. 2656] In the United States Patent Office

In Re Application of Guglielmo Marconi, Serial No. 36,010. Filed November 10, 1900. Apparatus for Wireless Telegraphy.

DISTRICT OF COLUMBIA,
County of Washington, ss:

Thomas E. Robertson, of Washington, in the District of Columbia, being duly sworn, deposes and says:

On the 9th day of July, 1903, I received from Messrs. Betts, Betts, Sheffield & Betts, of 120 Broadway, New York City, a petition, accompanied by a verified showing of Mr. L. F. H. Betts, for the revival of the above entitled application of G. Marconi; that this petition was forwarded to me with instructions to file in the Patent Office; that as no amendment accompanied the petition, I consulted the Law Clerk of the Patent Office regarding the matter and was informed that no matter how good the reasons for revival, the Commissioner invariably rules that under the law he has no power to revive any case in which an amendment is not presented;

That in view of the interview with the Law Clerk, the petition, with its verified showing, was not filed, but on the same day (July 9, 1903) I replied to the attorneys in [fol. 3657] fact informing them that an amendment would have to be filed with the petition.

A few days after this, on July 17, I received a letter from the attorneys in fact acknowledging the receipt of my letter and stating that they would re-forward the petition, with the amendment, as soon as the information arrived which they were expecting from Mr. Marconi who was then in Europe.

THOS. E. ROBERTSON.

Subscribed and sworn to before me this 24th day of February, 1904.

WM. H. DeLACY,
Notary Public.

[NOTARIAL SEAL.]

[fol. 3658] Paper No. 16

Serial No. 36010

Brief

Filed March 3, 1904

Docket Clerk, U. S. Patent Office, Mar. 3, 1904

United States Patent Office

In the Matter of Application of Guglielmo Marconi. Serial No. 36,010. Filed November 10, 1900. For Improvements in Apparatus for Wireless Telegraphy.

Brief on Request for Reconsideration of Petition to Revive

Hon. Commissioner of Patents,
Washington, D. C.

Sir:

This Application was rejected on the 3rd day of June, 1902. On the 12th day of October, 1903, a petition was filed, asking that the case be declared a pending application, under the authority vested in your Honor by the provisions of section 4894 of the Revised Statutes.

On December 2, 1903, this petition was denied on the ground that the attorneys made no attempt to consult the inventor for seven months after the rejection, and on the ground that when the inventor was consulted he failed to reply, and has failed to explain why he did not reply.

We ask for a reconsideration of this decision, in view of the additional showing contained in the affidavits of Mr. [fol. 3659] Marconi and Mr. L. F. H. Betts, attached to the request for reconsideration.

We believe that if the exact circumstances which controlled the proceedings in this case are presented to your Honor, as they present themselves to us, your Honor will be satisfied that the delay was "unavoidable" in the sense in which that term is used in section 4894 of the Revised Statutes.

From a consideration of section 4894 of the Revised Statutes, and of the decisions interpreting that section, and particularly of the decisions rendered by your Honor, we believe that it will be held that this application is not

abandoned, if it can be shown that during the whole period from June 3, 1902, to June 3, 1903, the applicant, and his attorneys, were using such diligence in the prosecution of this application as is generally used and observed by prudent and careful business men in relation to their most important affairs, and that the failure to file the amendment within the year was caused by happenings beyond the control of the applicant or his attorneys (Ex parte Pratt, C. D. 1887, p. 32; Ex parte Hiene, C. D. 1893, p. 106; Ex parte Stuckgold, 106 O. G., p. 544).

We believe that such a showing can be made, and is made, by the affidavits accompanying the request for reconsideration.

In the decision of December 2, 1903, your Honor said:

[fol. 3660] "This showing attempts to excuse the failure of the attorneys to act, by the statement that it was necessary to consult the inventor, but no effort whatever was made to consult the inventor for seven months after the Office Action."

Your Honor further, referring to the supplemental affidavit filed, and the showing therein of the movements of Mr. Marconi during the Summer and Fall of 1902, said:

"The movements of Mr. Marconi before coming to this country might be pertinent if they were what prevented the attorneys from communicating with him, but that does not appear to have been the case. No effort seems to have been made to communicate with him. It seems clear that the consultation might have been conducted by correspondence and that in fact seems to have been the intention after the interview of January 27, 1903."

We believe that the affidavits attached to the request for reconsideration will show that Mr. Marconi's movements were exactly what prevented his attorneys from communicating with him.

On the 18th day of June, 1902, Mr. Marconi began his experiments on the "Carlo Alberto," and from that time to the 1st of November, he was continuously occupied with these experiments. We were aware that he was traveling from place to place, at sea, and that communications addressed to him had very slight chance of reaching their destination.

It is true that Mr. Marconi twice returned to England during the time from June to November of 1902. It is also true that if letters had been addressed to him there they might have reached him, provided they had been held by the Marconi Company, Limited, pending his arrival, and not forwarded to him, and so followed him from place to place.

His attorneys, however, had been led to believe, and did believe, that as soon as Mr. Marconi arrived in England [fol. 3661] he would immediately sail for America. This was certainly Mr. Marconi's intention when he left England on the "Carlo Alberto." Influenced by this belief, his attorneys felt that it would be useless to address a communication to him in London, since they supposed that such a communication would, at best, be handed to him as he was about to sail for this country, and would, therefore, not secure for them the desired information any sooner than such information would be secured by awaiting his arrival in New York.

It thus appears that the most expeditious, as well as the most satisfactory, way to communicate with Mr. Marconi was to await his arrival in New York.

Acting on this information, and using their best judgment, his attorneys refrained from writing to Mr. Marconi. They did not, of course, at any time suppose that the delay would extend over more than a week or so.

The attorneys watched with considerable interest the subsequent postponements of Mr. Marconi's arrival in New York, but each time his arrival was postponed it still appeared that he would leave for New York before a letter could reach him.

Finally, alarmed by the repeated postponements, his attorneys wrote him, in January, 1903, at Cape Breton, with the results set forth in the affidavits attached to this request.

It thus appears that during the whole time from June, 1902, to January, 1903, there was no period in which this case was put aside and intentionally delayed.

[fol. 3662] It is submitted that the affidavits show that during this period, the attorneys for Mr. Marconi, though they did not actually write any letter in this case, were, nevertheless, exercising the greatest care and diligence in its prosecution, because the case was under constant consideration and everything was being done that the most careful person would do in the prosecution of his most important

business affairs. The attorneys for Mr. Marconi were at all times in possession of information which indicated to them that the most expeditious procedure possible was to await the arrival of Mr. Marconi in New York.

In the decision of December 2nd, and discussing the conduct of Mr. Marconi, your Honor said:

"He was consulted in January, 1903, however, and assuming that he was the one then called upon to act, there is no satisfactory explanation why he did not furnish the information desired. The suggestion is made that he was very busy upon other matters which he seems to have regarded as more important, but that is not a sufficient excuse for inaction. It does not appear that he was any more busy than at any other time. It appears merely that he was a busy man, and by choice devoted his attention to other matters instead of this."

The affidavits filed in connection with this petition show that Mr. Marconi left this country after the 27th of January, 1903. He could not have arrived in London earlier than the 4th of February. Prior to the 4th of April he had prepared and despatched the papers necessary in this case. It is thus seen that these papers were prepared within two months.

It is *now* shown that Mr. Marconi did actually act in this case, two months before the year elapsed, but his efforts came to naught as we never received the papers Mr. Marconi sent.

[fol. 3663] When it is considered that it was necessary for Mr. Marconi to look up records, and to prepare carefully drawn papers, in connection with this very technical subject, and when it is further remembered that this period was one in which the wonderful developments of wireless telegraphy, due to the efforts of Mr. Marconi, were in their most active stage; that Mr. Marconi was engaged in attending to the numerous experiments which were being carried on under his direction, over all Europe and in America and was also necessarily giving his personal attention to the organization of commercial companies to carry on the practical development of his system; and that, as the foremost figure in this new art, his personal services were demanded by many large interests, it is not believed that it can be said that he was negligent in requiring the space of two months to prepare these papers.

In view of this showing, it is not believed that your Honor will hold that in thus delaying for so short a time the forwarding of these papers, Mr. Marconi was guilty of negligence.

It must be remembered that Mr. Marconi had until the 3rd of June to amend his application. We do not, of course, contend that this would justify him in *intentionally* postponing action, but in preparing these papers within two months, Mr. Marconi certainly gave the matter as much attention as a prudent and careful business man would give to his most important business affairs.

[fol. 3664] These papers, which were despatched early in April, did not reach their destination; they were lost in transmission in some manner which has never been, and probably can never be, accounted for.

During the period immediately following the despatch of these papers by Mr. Marconi, when he supposed they were on their way to his attorneys and would arrive in due course, and his attorneys, relying on the information contained in the letter received April 19, 1903, in reply to their letter of March 20, 1903, also supposed that these papers were on their way and would arrive in due course, certainly no one can be blamed for negligence.

The attorneys for Marconi waited for these papers until May 13th, and again wrote to England urging that the papers be despatched immediately.

In the decision of December 2nd, your Honor said:

"The cablegram as to Marconi's illness was after the application was abandoned and thereafter (therefore) it does not appear that the illness had anything to do with the failure to act within the year."

It is believed that the affidavits *now* filed with this request show that Mr. Marconi's illness begun in the middle of April and thus prevented the filing of the amendment within the year.

The letter from the attorneys, of May 13th, was received by Marconi's Wireless Telegraph Company, Limited, on May 22nd. At that time Mr. Marconi was ill in Italy and unable to attend to business, and he did not recover suf-[fol. 3665] ficiently to attend to business until the middle of June. In the meantime, or on June 3rd, the year allowed by law, terminated.

It is believed that it has been shown that during this whole year everything had been done to forward the prosecution of this case that could in reason be asked. The case had been under constant consideration by the persons interested in its prosecution. All of these persons were certainly aware of the important interests involved, and were using the greatest care to see that these interests were properly and adequately protected.

The repeated and unexpected postponements of Mr. Marconi's visit to America, caused the postponement of action for seven months, but these postponements could not have been anticipated and there was no reason to suppose that the delay would be of any such length.

The fact that Mr. Marconi could not furnish the desired information without consulting his records in London, caused a further unexpected and unavoidable postponement of action.

Notwithstanding all this, papers were prepared which, but for their loss in the mail, would have made it possible to amend the case within the year.

Finally, at the very end of the year, when the loss of the papers was discovered, Mr. Marconi was incapacitated by a serious illness, and it became impossible to make the necessary amendment.

[fol. 3666] Immediately after the expiration of the year, on June 5, 1903, the attorneys for Marconi wrote a further letter to Marconi's Wireless Telegraph Co., Ltd., to ascertain why the necessary papers had not been sent. In reply to this letter they received a cablegram, dated July 3, 1903, saying that Mr. Marconi had been ill and that for this reason the papers had not been sent. The attorneys for Marconi then immediately took steps to protect his rights by preparing a petition, asking your Honor to declare that the case was not abandoned.

This petition was sent to Mr. Thomas E. Robertson, of 635 7th Street, Washington, on July 8th, and the attorneys for Marconi were informed by him that the petition must be accompanied by an amendment. They were, therefore, compelled to await the receipt of the information from Mr. Marconi.

On August 21, 1903, certain papers were received from Mr. Marconi, but these papers were insufficient to enable his attorneys to make the necessary amendment, and they were

compelled to await his arrival in New York, in the latter part of September, 1903. Upon his arrival, he was consulted in regard to this application, and on October 12th the proper amendment and petition were filed.

It will be noticed that the second time Mr. Marconi undertook to prepare these papers, it again required a period of two months. Even at this time, when Mr. Marconi knew that the papers should be furnished immediately, it was impossible for him to prepare them in less time.

[fol. 3667] On December 2nd, your Honor's decision, denying the petition, was rendered, and a copy of this decision was sent to Mr. Marconi by the first steamer leaving New York. Mr. Marconi immediately replied with a statement in regard to his illness during the period from the middle of April to the middle of June, 1903, and instructing his attorneys to ask for a reconsideration of the petition, in view of the additional showing which he could make, and which your Honor had indicated, in the last paragraph of the decision of December 2nd, was necessary.

Mr. Marconi's attorneys, by the next steamer, sent to him an outline of the affidavit desired, and he immediately drew up the necessary affidavit and returned it to his attorneys, by whom it was received on the 15th day of February 1904. The affidavit, together with a supplemental affidavit of Mr. Betts, and a request for reconsideration, were forwarded to Washington on February 20th.

In the prosecution of this application, the failure to file the necessary amendment was undoubtedly caused by a loss of papers in the mail, that is, by an accident beyond the control of the applicant, and unavoidable.

There have been a number of cases in the history of the Patent Office, and even during your Honor's administration, in which failure to file the necessary amendment has been caused directly by an unavoidable accident occurring near the end of the period allowed by law, and in which cases it has been held that the delay was not "unavoidable" within [fol. 3668] the meaning of that term as used in section 4894 of the Revised Statutes.

In each of these cases, however, there has been some period through the year in which the application was deliberately laid aside with the intention of postponing action for some purpose or other, or else, the actions which were taken by the applicant have not been bona fide attempts to further the prosecution of the applications.

In the present case, there has never been any such period of intentional delay, and there has never been taken any action which was not a bona fide attempt to further the prosecution.

We have been unable to find any case which has been held to be abandoned where there has been, during the whole year, a bona fide attempt to amend the application as soon as possible.

It is believed that it has been shown that in this case there has been such a bona fide attempt.

Favorable action on the petition is respectfully asked.

Respectfully submitted,

BETTS, BETTS, SHEFFIELD & BETTS,
Attorneys for Marconi.

Dated, New York, February 29, 1904.

[fol. 3669] Letter No.

E. E. G.

Department of the Interior, United States Patent Office,

Washington, D. C. March 29, 1904.

Serial No. 36,010, Paper No. 17

Notice of Comm'rs decision, Dated 190 .

Petition for Reconsideration of Question of Abandonment

In the matter of the Application of Guglielmo Marconi, Apparatus for Wireless Telegraphy; Filed Nov. 10, 1900, Serial No. 36,010.

Sir:

You are hereby informed that the above petition has been granted by the Commissioner. Please find enclosed herewith a copy of the decision.

By direction of the Commissioner:

Very respectfully,

C. M. IRELAN,
Chief Clerk.
F

Guglielmo Marconi,
c/o Thos. E. Robertson
#605 Seventh St.,
Washington, D. C.

[fol. 3670] M. H.

Serial No. 36,010, Paper No. 17, Comm'rs decision—Recorded Vol. 79, Page 209, United States Patent Office.

Ex parte GUGLIELMO MARCONI.

Apparatus for Wireless Telegraphy.

Petition.

Application filed November 10, 1900, No. 36,010.

Messrs. Betts, Betts, Sheffield & Betts and Mr. T. E. Robertson for applicant.

This is a petition for a reconsideration of the question of abandonment of the above-entitled application.

In the decision dated December 2, 1903, it was held that the application must be regarded as abandoned in the absence of a more complete showing of the reasons for the delay than that included in the affidavits then filed. The present petition is supported by an affidavit of the inventor and by affidavits of one of the principal attorneys and an associate.

It appears that the inventor was traveling during many months immediately after the last office letter, and that it was difficult to communicate with him. By reason of the character of the invention, it was necessary for the attorneys to obtain his advice and assistance in replying to the examiner's action, and since he was constantly expected to come to this country, the attorneys postponed action until his arrival. Various circumstances interfered with his plans to visit this country, and his visit was postponed from [fol. 3671] time to time. When he did arrive, in January, 1903, he was consulted about this application, but found it necessary to refer to his papers in London before giving his instructions. This was five months before the year allowed by law expired. Upon returning to London the inventor prepared the papers, giving his attorneys instructions, and left them with a notary early in April, 1903, to be forwarded, but they were never received by the attorneys. It is not clear what became of them. For two months after April 15, 1903, the inventor was incapacitated for business by illness, and although the attorneys were active in seeking the

information to be used as the basis for a reply to the examiner's action, the inventor was unable to furnish it. Upon his recovery, he again prepared his instructions to his attorneys and forwarded the papers to them, and upon a second trip to this country gave them oral advice. Responsive action was then taken in the case.

Under all of the circumstances, it must be held that reasonable diligence was exercised in preparing a response to the last office action and that the delay was unavoidable.

The petition is granted.

F. I. ALLEN,
Commissioner.

March 28, 1904.

[fol. 3672] 2—260

Div. XVI, Room 109

Paper No. 18

C. E. N.

Address only "The Commissioner of Patents, Washington, D. C.," and not any official by name.

All communications respecting this application should give the serial number, date of filing, title of invention, and name of the applicant.

Department of the Interior, United States Patent Office,
Washington, D. C.

March 31, 1904.
Mailed " " "

G. Marconi,
c/o T. E. Robertson,
605 7th Street,
Washington, D. C.

Please find below a communication from the Examiner
your
in charge of [the]* ^ application [of]* #36,010, filed November 10, 1900, for Apparatus for Wireless Telegraphy.

F. I. ALLEN,
THOMAS EWING,
Commissioner of Patents.

[*Words and figures enclosed in brackets erased in copy.]

This application having been revived by the Commissioner, applicant's amendment of October 12, 1903, has been entered as corrected by his amendment of October 24, 1903. The following action is taken:

The claims are all allowed except claims 4, 5, 6 and 7, which are rejected on the patent to Stone, 714,756, December 2, 1902, application filed February 8, 1900.

Stone shows in Fig. 5 a transformer M whose secondary I_2 is connected to an open circuit including a radiating conductor V at one end and a capacity E at the other and whose primary I_1 is connected to a condenser circuit discharging through a spark gap, viz., the circuit C s I_1 L. These circuits are in "electrical resonance with each other",—see lines 16-20, page 2. It is not stated how the elevated conductor is given a natural period equal to that of the oscillations impressed upon it but it is well-known by all skilled in this art that this may be accomplished by adjusting the length of the elevated conductor, thereby adjusting the distributed capacity and the distributed inductance of the same until the natural period of such conductor is equal to the [fol. 3673] natural period of the condenser circuit C sI_1 L. =36,010.

[fol. 3673] When this is done "the frequency impressed upon the elevated conductor" is "the same as the natural period or fundamental of such conductor", to quote from the Stone patent.

Applicant discloses another means whereby the same result may be effected, viz., by including a "variable inductance" in the elevated conductor. All claims which include this element are considered allowable over the Stone patent.

In regard to claim 7 it may be said that Stone states that the operator at each station may at will adjust his apparatus in such way as to place himself in communication with any other station (page 4, lines 28-36) and that he also states that this result may be effected by making the coil L of the condenser circuit adjustable (page 6, lines 76-81). Inasmuch as the period of an oscillating circuit depends upon the capacity of the condenser in the same way that it depends upon the inductance of the coil, it is held that it is not patentable to make the condenser c of applicant's oscillating circuit adjustable for the same purpose as Stone makes the coil L of his oscillating circuit adjustable.

Claims 4, 5, 6 and 7 will be allowed if amended by inserting the words *a variable inductance and* after the word "including" in line 3 of each claim.

In claim 8, line 6, the words "said circuit" are repeated and should be canceled.

CAMPBELL,
Examiner, Division XVI.

G. K. W.

[fol. 3674] Patent Office, Jun. 1, 1904, Div. 16. Filed

Mail Room, May 31, 1904, U. S. Patent Office

Serial No. 36010

Paper No. 19

Amend't F

Filed May 31, 1904

United States Patent Office

In Re Application of Guglielmo Marconi, Serial No. 36,010, for Apparatus for Wireless Telegraphy, Filed November 10, 1900

Amendment

New York,
May 28, 1904.

Hon. Commissioner of Patents,
Washington, D. C.

Sir:

We authorize and request the following amendment of the Specification of this Application:

In line 10 of page 1, after "tions," insert "or electric waves."

In line 12, same page, after "oscillations", insert "or electric waves."

In line 13, same page, before "selected", insert "one."

In line 1 of page 2, cancel "only."

In line 19 of same page, insert before "a spark producer", the words

F'. "a producer of Hertzian oscillations or electric waves shown in the form of."

In the same line, insert "an" before "induction coil."

Same page, at the end of line 24, insert "a device responsive to electric waves, such as."

In line 13 of page 3, change "Ruhmkorff" to "induction."

In line 17, same page, insert before "oscillation producer," the words electric wave or."

In lines 23 and 24 of same page, substitute "induction" for "Ruhmkorff."

[fol. 3675] After the end of line 28 of same page, insert

F². "It is obvious that instead of the induction coil and associated parts for producing the electric waves or oscillations, I may use any other proper means for producing such waves or oscillations, such, for instance, as a generator of alternating electric currents."

In line 15 of page 4, substitute "induction" for "Ruhmkorff."

In line 23, same page, after "radiated," insert "in the form of electric waves."

5

Exr. In line 10 of page [4]*, before "oscillations", Insert "waves or."

Before the paragraph beginning in line 11 of page 5, insert a paragraph as follows:

F³. "As a responder to electric waves, I may use at the receiving station any of the now well known forms of such devices such as those which depend for their action on the reduction of the resistance of a metallic microphone by the action of electric waves, or 'coherers', one form of which is disclosed in my patent No. 586,193; or I may employ one which depends for its action on the increase of the resistance of the device under the influence of the electric waves, or 'anti-coherers', such as described by Branly in 'La Lumiere Electrique' of June 13, 1891; or I may use those which depend upon the action of an electric

[*Words and figures enclosed in brackets erased in copy.]

wave as a magnetizing or demagnetizing agency, such as I have disclosed in my application No. 132,974, filed November 28, 1902; or I may use various other well known devices such as the electrolytic, electro- [fol. 3676] thermal, electromagnetic or electrodynamic responders."

In lines 22, 23 and 25 of page 5, cancel "pending application, serial No. — filed February 21, 1901, for "and insert after "United States," "No. 676,332," unless this has *already been done*.

In line 15 of page 6, change "detector" to "wave responsive device."

On the same page, cancel the paragraph beginning at line 16 and ending in line 23, and substitute therefor the following:

F⁴. —"The capacity and self-induction of the four circuits—i. e., the primary and secondary circuits at the transmitting station and the primary and secondary circuits at any one of the receiving stations, in a communicating system—are each and all to be so independently adjusted as to make the product of the self-induction multiplied by the capacity, the same in each case, or multiples of each other, that is to say, the electrical time periods of the four circuits are to be the same, or octaves of each other."

On page 7, line 7, cancel "the" and substitute "any or all of the four."

Cancel claims 4 and 5 and substitute therefor the following:

F⁵. "4. In a system of syntonic wireless telegraphy, a circuit so arranged as to form a persistent oscillator, a circuit so formed as to constitute a good radiator in inductive relation thereto, means for inducing in the oscillator circuit electric undulations of a predetermined period, and means for attuning the natural [fol. 3677] period of vibration of each of said circuits to the period of the undulations so induced.

F⁵. 5. An element of an apparatus employed in a system of telegraphy by electric waves or oscillations of high frequency, comprising a conductor elevated at

one end and connected to capacity at the other end, said conductor including a variable inductance and an element having appreciable capacity."

In claim 6, line 8, insert "each of" before "the two circuits."

Cancel claim 7 and substitute therefor:

F[6]. "7. An element of an apparatus employed in a system of telegraphy by electric waves or oscillations of high frequency, comprising an open circuit so arranged as to constitute a radiator of such waves or oscillations, and means for varying at will the natural period of vibration of the said circuit."

In claim 11, lines 5 and 6, cancel "sparking device" and substitute "producer of electric waves of high frequency."

In claim 12, line 5, cancel "sparking device" and substitute "producer of electric waves of high frequency."

In claim 19, line 9, cancel "imperfect contact" and substitute "wave responsive."

In claim 20, line 5, cancel "oscillations" and substitute "electric waves."

[fol. 3678] Remarks

The claims now presented, all include an elevated conductor, or a circuit which is a good radiator of electric waves or oscillations, and means for adjusting the tune of such elevated conductor or radiating circuit. It is believed that the Examiner recognizes the fact that the Stone Patent does not show such an arrangement, and an early allowance is requested.

Respectfully submitted,

BETTS, BETTS, SHEFFIELD & BETTS,

Attorneys for Applicant.

(Here follow 2 photolithographs, side folios 3679-3680)

4074A

A

2—181.

Serial No. 36010

Division.

Communications should be addressed to
Commissioner of Patents,
Washington, D. C.

DEPARTMENT OF THE INTERIOR,

U. S. Patent Office,

Washington, D. C., June 1, 1904

Guglielmo Marconi, Assor.

c/o T. B. Robertson,

City

SIR:—Your APPLICATION for a patent for an IMPROVEMENT IN

Apparatus for Wireless Telegraphy

Filed Nov. 10, 1900, has been examined and ALLOWED.

The final fee, **Twenty Dollars**, must be paid, and the Letters Patent bear date as of a day not later than SIX MONTHS from the time of this present notice of allowance.

If the final fee is not paid within that period the patent will be withheld, and your only relief will be by a renewal of the application, with additional fees, under the provisions of Section 4897, Revised Statutes. The Office aims to deliver patents upon the day of their date, and on which their term begins to run; but to do this properly applicants will be expected to pay their final fees at least TWENTY DAYS prior to the conclusion of the six months allowed them by law. The printing, photolithographing, and engrossing of the several patent parts, preparatory to final signing and sealing, will consume the intervening time, and such work will not be done until after payment of the necessary fees.

When you send the final fee you will also send, DISTINCTLY AND PLAINLY WRITTEN, the name of the INVENTOR and TITLE OF INVENTION AS ABOVE GIVEN, DATE OF ALLOWANCE (which is the date of this circular), DATE OF FILING, and, if assigned, the NAMES OF THE ASSIGNEES.

If you desire to have the patent issue to ASSIGNEES, an assignment containing a REQUEST to that effect, together with the FEE for recording the same, must be filed in this Office on or before the date of payment of final fee.

After issue of the patent uncertified copies of the drawings and specifications may be purchased at the price of **5 cents each**. The money should accompany the order. Postage stamps will not be received.

Respectfully,

F. I. Allen.

Commissioner of Patents.

After allowance, and prior to payment of the final fee, applicants should carefully scrutinize the description to see that their statements and language are correct, as mistakes not incurred through the fault of the office, and not affording legal grounds for reissues, will not be corrected after the delivery of the letters patent to the patentee or his agent.

IN REMITTING THE FINAL FEE GIVE THE SERIAL NUMBER AT THE HEAD OF THIS NOTICE

If payment is made by check or draft, the credit allowed is subject to the collection of the same.

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MEMORANDUM

OF

FEE PAID AT UNITED STATES PATENT OFFICE.

(Be careful to give correct Serial No.)

Serial No. 36,010, *1900*

INVENTOR:

GUGLIELMO MARCONI

PATENT TO BE ISSUED TO

As Assigned.

NAME OF INVENTION, AS ALLOWED:

Apparatus for Wireless Telegraphy.

DATE OF PAYMENT:

June 9th, 1902.

FEE:

Final $20.00

DATE OF FILING:

Nov. 10, 1900

DATE OF CIRCULAR OF ALLOWANCE:

June 1, 1904.

The Commissioner of Patents will please apply the accompanying fee as indicated above.

Thos E. Robertson

Attorney.

SEND PATENT TO

Attorneys.

6—1846

[fol. 3681] Serial No. 36,010

C.R.

Department of the Interior, United States Patent Office,
Washington, D. C.

June 9, 1904.

Guglielmo Marconi, Assor.,
% Thos. E. Robertson,
605 7th St.,
Washington, D. C.

SIR:

You are informed that the final fee of Twenty Dollars has been received in your application for Improvement in Apparatus for Wireless Telegraphy.

Very respectfully,

F. I. ALLEN,
Commissioner of Patents.

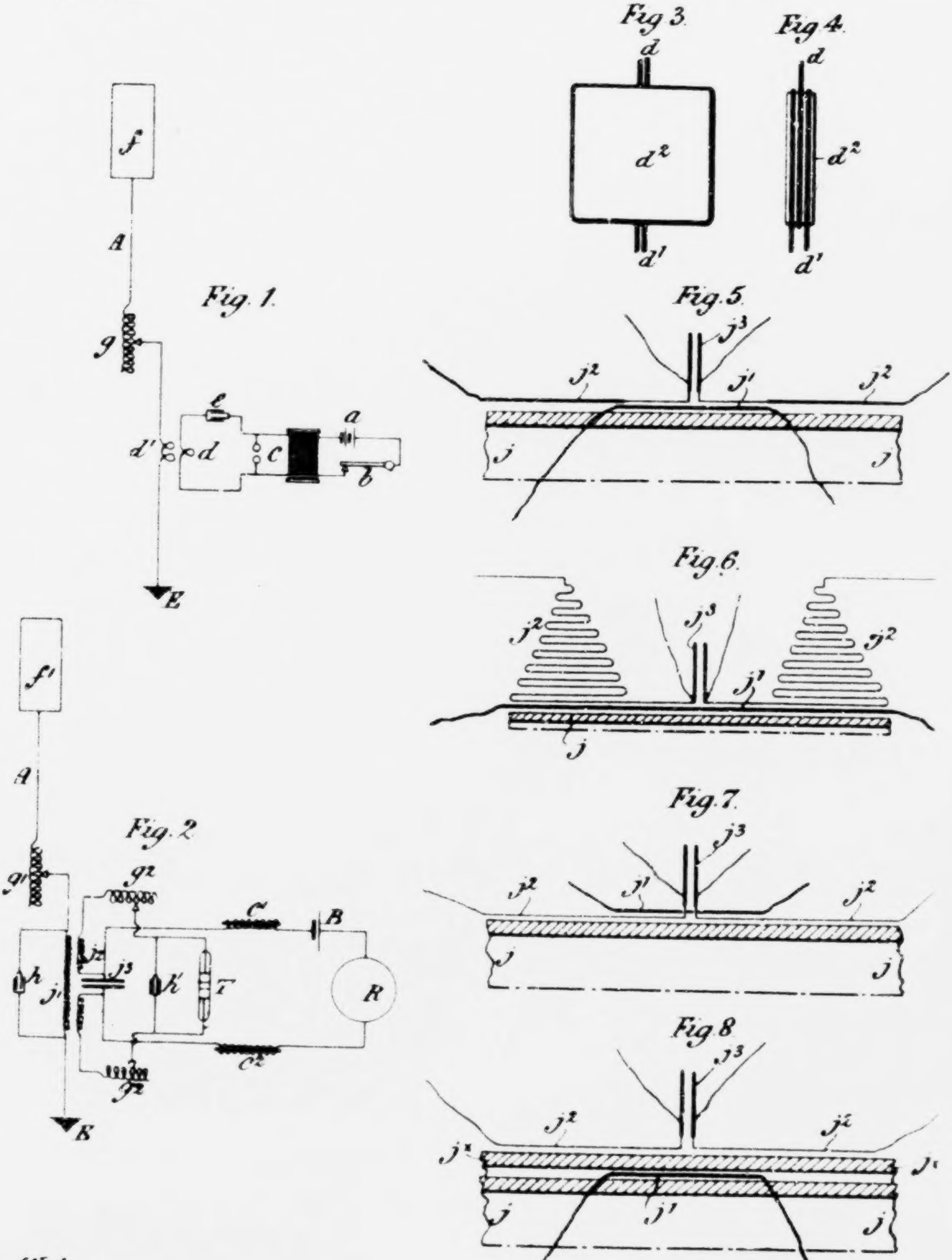
No. 763,772. PATENTED JUNE 28, 1904.

G. MARCONI.

APPARATUS FOR WIRELESS TELEGRAPHY.

APPLICATION FILED NOV. 10, 1900.

NO MODEL.



Witnesses
[illegible]
[illegible]

Inventor
GUGLIELMO MARCONI, By
Betts, Betts, Sheffield & Betts
HIS ATTORNEYS

UNITED STATES PATENT OFFICE.

GUGLIELMO MARCONI, OF LONDON, ENGLAND, ASSIGNOR TO MARCONI'S WIRELESS TELEGRAPH COMPANY, LIMITED, OF LONDON, ENGLAND.

APPARATUS FOR WIRELESS TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 763,772, dated June 28, 1904.

Application filed November 10, 1900. Serial No. 36,010. (No model.)

To all whom it may concern:

Be it known that I, GUGLIELMO MARCONI, electrician, a subject of the King of Italy, residing and having a post-office address at 18 Finch Lane, Threadneedle street, in the city of London, England, have invented certain new and useful Improvements in Apparatus for Wireless Telegraphy, of which the following is a specification.

My invention relates to apparatus for communicating electrical signals without wires and by means of Hertz oscillations or electric waves; and the object of the invention is to increase the efficiency of the system and to provide new and simple means whereby oscillations or electric waves from a transmitting-station may be localized when desired at any one selected receiving station or stations out of a group of several receiving-stations.

In my prior United States patent No. 586,193 (Reissue No. 11,913, dated June 4, 1901) I have shown and described the combination at a transmitting-station of an oscillation-producer, such as an induction-coil, having one end of its secondary coil connected to one contact of a spark-producer and to the earth and having the other end of the said secondary connected to the opposite contact of the spark-producer and to a vertical wire or elevated plate, and I have further shown at a receiving-station an imperfect contact connected in circuit with a vertical receiving-wire and with the earth. According to the present invention the system includes at the transmitting-station the combination, with an oscillation-transformer of a kind suitable for the transformation of very rapidly alternating currents, of a persistent oscillator, and a good radiator, one coil of said transformer being connected between the aerial wire or plate and the connection thereof to earth, while the other coil of the transformer is connected in circuit with a condenser, a producer of Hertzian oscillations or electric waves shown in the form of a spark-producer, and an induction-coil (constituting the persistent oscillator) controlled by a signaling instrument. The complete system also includes at a receiving-station an oscillation-transformer one coil whereof is included between the aerial receiving-wire and earth, constituting a good absorber of electrical oscillations, while a device responsive to electric waves, such as an imperfect contact or a device for operating the same, is included in a circuit with the other coil of said transformer. The system also requires as essential elements thereof the inclusion in the lines (at both stations) from the aerial conductor to the earth of variable inductances and the use at both stations of means for varying or adjusting the inductance of the two circuits at each station to accord with each other. By this arrangement of apparatus I am able to secure a perfect "tuning" of the apparatus at a transmitting-station and at one or more of a number of receiving-stations.

Referring to the accompanying drawings, Figure 1 indicates diagrammatically the arrangement of apparatus at a transmitting-station. Fig. 2 indicates diagrammatically the arrangement of apparatus at a receiving-station. Figs. 3 and 4 are views, plan and side, of the preferred form of transformer at the transmitting-station. Figs. 5, 6, 7, and 8 are diagrammatic views of forms of transformers at the receiving-station.

The transmitting-station is provided under my present invention with a source *a* of current electrically connected in circuit with the primary of an induction-coil *c* and with a circuit-closing key *b* or otherwise controlled by a signaling instrument. In the secondary circuit of said induction-coil the spherical terminals or other contacts of a spark-producer or other electric-wave or oscillation producer are included with a shunt therefrom, in which shunt is included the primary coil *d* of an oscillation-transformer, such as *d'*. A condenser *e*, preferably one provided with two telescoping metallic tubes separated by a dielectric and arranged to readily vary the capacity by being slid upon each other, is included in one connection from the induction-coil to the transformer-winding *d*. The secondary coil *d'* of the transformer is connected (at one end) to the earth E and at its other end to a vertical wire A or an elevated plate *f*.

It is obvious that instead of the induction-

coil and associated parts for producing the electric waves or oscillations I may use any other proper means for producing such waves or oscillations—such, for instance, as a generator of alternating electric currents.

The illustrated arrangement of parts at a transmitting-station enables much more energy to be imparted to the radiator *f*, the approximately closed circuit of the primary being a good conserver and the open circuit of the secondary being a good radiator of wave energy. My experiments have demonstrated that the best results are obtained at the transmitting-station when I use a persistent oscillator—an electrical circuit of such a character that if electromotive force is suddenly applied to it and the current then cut off electrical oscillations are set up in the circuit which persist or are maintained for a long time—in the primary circuit and use a good radiator—*i. e.*, an electrical circuit which very quickly imparts the energy of electrical oscillations to the surrounding ether in the form of waves—in the secondary circuit.

In operation the signaling-key *b* is pressed, and this closes the primary of the induction-coil. Current then rushes through the transformer-circuit and the condenser *e* is charged and subsequently discharges through the spark-gap. If the capacity, the inductance, and the resistance of the circuit are of suitable values, the discharge is oscillatory, with the result that alternating currents of high frequency pass through the primary of the transformer and induce similar oscillations in the secondary, these oscillations being rapidly radiated in the form of electric waves by the elevated conductor.

For the best results and in order to effect the selection of the station or stations whereat the transmitted oscillations are to be localized I include in the open secondary circuit of the transformer, and preferably between the radiator *f* and the secondary coil *d'*, an inductance-coil *g*, Fig. 1, having numerous coils, and the connection is such that a greater or less number of turns of the coil can be put in use, the proper number being ascertained by experiment.

At the receiving-stations employing my present invention I prefer to use a receiver such as those described in my several United States Patents, Nos. 586,193, 627,650, 647,007, 647,008, 647,009, and 668,315, capable of being affected by electrical waves or oscillations of high frequency.

As a responder to electric waves I may use at the receiving-station any of the now well-known forms of such devices, such as those which depend for their action on the reduction of the resistance of a metallic microphone by the action of electric waves or "coherers," one form of which is disclosed in my Patent No. 586,193, or I may employ one which depends for its action on the increase of the resistance of the device under the influence of the electric waves or "anticoherers," such as described by Branly in *La Lumiere Electrique* of June 13, 1891, or I may use those which depend upon the action of an electric wave as a magnetizing or demagnetizing agency, such as I have disclosed in my application Serial No. 132,974, filed November 28, 1902, or I may use various other well-known devices, such as the electrolytic, electrothermal, electromagnetic, or electrodynamic responders.

Referring to Fig. 2, *f'* indicates a plate or cylinder (not essential at either transmitter or receiver) at the upper end of an elevated conductor A, which is connected to the primary coil *j'* of a transformer or induction-coil and thence to earth E. In a shunt around said primary *j'* I usually place a condenser *h*, preferably similar in construction and operation to the condenser *e*. An inductance-coil *g'* of variable inductance is interposed in the primary circuit of the transformer, being preferably located between the cylinder *f'* and the coil *j'*, and the inductance of said coil may be adjusted in accordance with the method described by me in my Letters Patent of the United States No. 676,332 to harmonize with the inductance of coil *g* at the transmitting-station, Fig. 1 of the accompanying drawings, or with that of the coil or coils at one or more of the transmitting-stations included in the communicating system.

The secondary coil j^2 of the transformer is wound in two parts, preferably as described in my United States Letters Patent No. 668,315, dated February 19, 1901, and the outer ends of said coil are connected in certain cases through one or more interposed inductance-coils g^2, preferably of variable inductance, with the terminals of a coherer T or other detector of electrical oscillations. The inner ends of the split secondary coil are connected to the plates of a condenser j^3. A condenser *h'* is sometimes included in a shunt around the detector T. B is a battery, and R a relay connected to the condenser j^3 and controlling a telegraphing instrument or a printing device. *c'* and c^2 are choking-coils preventing oscillations from the secondary j^2 running into the battery-circuit and thereby confining them to the wave-responsive device.

The capacity and self-induction of the four circuits—*i. e.*, the primary and secondary circuits at the transmitting-station and the primary and secondary circuits at any one of the receiving-stations in a communicating system—are each and all to be so independently adjusted as to make the product of the self-induction multiplied by the capacity the same in each case or multiples of each other—that is to say, the electrical time periods of the four circuits are to be the same or octaves of each other.

In employing this invention to localize the

transmission of intelligence at one of several receiving-stations the time period of the circuits at each of the receiving-stations is so arranged as to be different from those of the other stations. If the time periods of the circuits of the transmitting-station are varied until they are in resonance with those of one of the receiving-stations, that one alone of all of the receiving-stations will respond, provided that the distance between the transmitting and receiving stations is not too small.

The adjustment of the self-induction and capacity of any or all of the four circuits can be made in any convenient manner and employing various arrangements of apparatus, those shown and described herein being preferred. In practice I have found the following preferred details of arrangements of apparatus to work well: The aerial conductors A at all stations and the conductor for the transformer-windings at the receiving-stations are composed of seven strands of copper wire .889 millimeters in diameter. The transformer at the transmitting-station may be of any of the following forms:

1. Around a block or core d^{7}, preferably a square block—say .17 meters wide—of insulating material is wound a primary coil d in length .946 meters, while the secondary d' consists of two turns or squares, one lying on each side of the primary. (See Figs. 3 and 4.) The insulation of both primary and secondary consists of 1.25 millimeters of rubber and one millimeter of jute, making a total thickness of 2.25 millimeters.

2. A transformer in all essential respects similar to 1, but with a primary of 1.93 meters and the core or block on which both primary and secondary are wound, is .3048 meters wide.

3. A transformer having a cylindrical core 10.16 centimeters in diameter and with a primary having ten turns wound thereon; over this, but separated by two millimeters of paper or other insulant, the secondary, also of ten turns.

Various forms of transformers, &c., which may be employed by me are described in my British Patent No. 7,777 of 1900.

The inductance-coils g and g' are preferably of copper wire 6.25 millimeters in diameter, wound on a cylinder 10.64 centimeters in diameter, with an interval of 2.28 millimeters between adjacent turns. The inductance-coils g^{2} at the receiving-station are preferably of silk-covered copper wire .19 millimeter diameter wound upon cylinders 3.7 centimeters in diameter.

Various forms of induction-coils j' j^{2} may be used. Figs. 5, 6, 7, and 8 show details of different forms. The figures show diagrammatically greatly-enlarged longitudinal sections not strictly to scale. Instead of showing the section of each coil or layer of wire as a longitudinal row of dots or small circles, as it would actually appear, it is for simplicity shown as a continuous longitudinal straight line.

Referring to Fig. 5, the primary j' preferably consists of 3.046 meters of silk-covered copper wire, say, and seventy-one millimeters in diameter wound in one layer on a core of ebonite or other insulating material 2.9 centimeters in diameter. Insulating material is wound over and on each side of this, so as to make a cylindrical core, say, 3.13 centimeters in diameter, on which is wound the secondary, each half of which consists of 6.4 meters of silk-covered copper wire .19 millimeter in diameter joined to 13.41 meters of silk-covered copper wire .37 millimeter in diameters wound in the same sense as the primary, the thinner wire being over the primary and the thicker being beyond the ends thereof.

The form of induction-coil shown in Fig. 6 has a primary of one hundred turns of copper wire .037 centimeters in diameter wound on a core j (2.9 centimeters in diameter) with a single silk covering and coated with paraffin-wax. The secondary j^{2} is of copper wire .019 in diameter, insulated with a single silk covering, and is wound over the primary, commencing in the middle and in the same way as the primary. Each half of the secondary is in layers of the following number of turns: first layer, seventy-seven turns; second layer, forty-nine turns; third layer, forty-six turns; fourth layer, forty-three turns; fifth layer, forty turns; sixth layer, thirty-seven turns; seventh layer, thirty-four turns; eighth layer, thirty-one turns; ninth layer, twenty-eight turns; tenth layer, twenty-five turns; eleventh layer, twenty-two turns; twelfth layer, nineteen turns; thirteeth layer, sixteen turns; fourteenth layer, thirteen turns; fifteenth layer, ten turns; sixteenth layer, seven turns; and seventeenth layer, three turns, making five-hundred turns in all.

A third form of induction-coil (shown in Fig. 7) has a primary of 3.048 meters of silk-covered copper wire .19 millimeter in diameter and a secondary of 30.48 meters of silk-covered copper wire .1 millimeter in diameter wound in one layer on a core four centimeters in diameter, the primary being in one layer outside of the secondary.

The fourth form of induction-coil is shown in Fig. 8. Its primary consists of 3.048 meters of silk-covered copper wire .37 millimeter in diameter wound on a core 2.9 centimeters in diameter and inserted in a tube j^{x} of four centimeters external diameter, on which is wound the secondary of 27.432 meters of silk-covered copper wire .12 millimeter in diameter, the break at the middle of the secondary being over the middle of the primary.

Other forms of transformers which may be employed by me are described and claimed in my British Patent No. 7,777 of 1900.

The following tables give preferred adjustments, those details opposite any tune in the transmitting-station table being of course used in connection with those opposite the same tune in the receiving-station table:

Transmitting-Station.

Tune	Aerial conductor	Transformer d d'	Inductance number of turns of g included	Capacity microfarads e	Length of spark in millimeters
No. 1	36.576 meters of cable	No. 1.	None.	.007984	8
No. 2	do	No. 1.	45	.016886	4
No. 3	do	No. 2.	None.	.004112	3
No. 4	do.	No. 2.	100	.010849	4
No. 5	Zinc cylinder 9.144 meters long, 1.524 meters in diameter, and hoisted 3.048 meters above ground.	No. 2.	None.	.001600	12.5
No. 6	30.48 meters of cable.	No. 2.	None.	.000878	4

Receiving-Station.

Tune	Induction-coil.	Capacity in microfarads of—		Inductance introduced in—	
		h.	h'	g'. Number of turns.	g^2.
No. 1.	No. 1.	Omitted.	Omitted.	None.	None
No. 2.	No. 1.	Omitted.	.0004	45	None.
No. 3.	No. 2	.0046	Omitted	Up to 21 may be inserted.	None.
No. 4.	No. 2	.0046	Omitted	100	2 coils of 15.24 meters at each end of secondary.
No. 5.	No. 3.	Omitted.	Omitted.	None.	None.
No. 6.	No. 4.	Omitted.	Omitted.	None.	None

It will be observed that both the transmitter and the receiver are the same for tunes 1 and 2 and that when the capacity of the condenser e is varied the two stations can be brought into tune by including forty-five turns of each of the coils g g' and by introducing a condenser h' of small capacity in parallel with the coherer T. Similarly the transmitter and receiver are the same for tunes 3 and 4, and when the capacity of e is varied the stations are tuned by including one hundred turns of each of the coils g and g' and by also including the coils g^2.

While I have herein shown and described details of construction and of arrangement found by me to be useful, yet I do not wish to be understood as confining my claims thereto. Obviously modifications which are within my invention will readily suggest themselves to skilled persons.

What I claim is—

1. At a station employed in a wireless-telegraph system, a signaling instrument comprising an induction-coil, the secondary circuit of which includes a condenser discharging through a means which automatically causes oscillations of the desired frequency; an open circuit electrically connected with the oscillation-producer aforesaid and a variable inductance included in the open circuit, substantially as and for the purpose described.

2. At a station employed in a wireless-telegraph system, an oscillation-receiving conductor, a variable inductance connected with said conductor; a wave-responsive device electrically connected with said conductor and in circuit with a condenser, substantially as and for the purpose described.

3. At a station employed in a wireless-telegraph system, a signaling instrument comprising an induction-coil, the secondary circuit of which includes a condenser discharging through a means which automatically causes oscillations of the desired frequency, and the

primary circuit of which includes a generator; means for varying the primary circuit; an open circuit electrically connected with the oscillation-producer aforesaid, and a variable inductance included in the open circuit, substantially as and for the purpose described.

4. In a system of syntonic wireless telegraphy, a circuit so arranged as to form a persistent oscillator, a circuit so formed as to constitute a good radiator in inductive relation thereto, means for inducing in the oscillator-circuit electric undulations of a predetermined period, and means for attuning the natural period of vibration of each of said circuits to the period of the undulations so induced.

5. An element of an apparatus employed in a system of telegraphy by electric waves or oscillations of high frequency, comprising a conductor elevated at one end and connected to capacity at the other end, said conductor including a variable inductance and an element having appreciable capacity.

6. At a transmitting-station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating-conductor at one end and capacity at the other end, and whose primary is connected to a condenser-circuit discharging through a means which automatically causes oscillations of the desired frequency, and means for adjusting the oscillation period of each of the two circuits connected with the transformer to bring them into accord with each other, substantially as described.

7. An element of an apparatus employed in a system of telegraphy by electric waves or oscillations of high frequency, comprising an open circuit so arranged as to constitute a radiator of such waves or oscillations, and means for varying at will the natural period of vibration of the said circuit.

8. At a transmitting-station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating-conductor at one end and capacity at the other end, a variable inductance being included in said circuit, and whose primary is connected to a condenser-circuit discharging through a means which automatically causes oscillations of the desired frequency, substantially as described.

9. At a transmitting-station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating-conductor at one end and capacity at the other end, a variable inductance being included in said circuit, and whose primary is connected in series with an adjustable condenser and with a means which automatically causes oscillations of the desired frequency, substantially as described.

10. A system of wireless telegraphy, in which the transmitting-station and the receiving-station each contains an oscillation transformer, one circuit of which is an open circuit and the other a closed circuit, the two circuits at each station being in electrical resonance with each other and in electrical resonance with the circuits at the other station, substantially as described.

11. In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a transmitting-station, of an induction-coil; an electric circuit containing the secondary of said coil, a condenser and the primary coil of the oscillation-transformer; a producer of electric waves of high frequency electrically connected with the secondary of the induction-coil: a signaling instrument in circuit with the primary of the induction-coil; the secondary coil of the oscillation-transformer electrically connected, at one end to capacity and, at the other end, to an inductance, and an aerial conductor connected to the inductance, substantially as and for the purpose described.

12. In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a transmitting-station, of an induction-coil; an electric circuit containing the secondary of the said coil, a condenser and the primary coil of the oscillation-transformer; a producer of electric waves of high frequency connected with the secondary of the induction-coil; a signaling instrument in circuit with the primary of the induction-coil; the secondary coil of the oscillation-transformer electrically connected, at one end, to capacity and, at the other end, to a variable inductance, and an aerial conductor connected to the variable inductance, substantially as and for the purpose described.

13. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a variable inductance being included in said circuit, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and a condenser in circuit with the wave-responsive device, substantially as described.

14. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and means for adjusting the two transformer-circuits in electrical resonance with each other, substantially as described.

15. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a condenser located in said circuit between the coil and the capacity, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and means for adjusting the two transformer-circuits in electrical resonance with each other, substantially as described.

16. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, an adjustable condenser in a shunt connected with the open circuit and around said transformer-coil, a wave-responsive device electrically connected with the other coil of the oscillation-transformer, and means for adjusting the two transformer-circuits in electrical resonance with each other, substantially as described.

17. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and means included in each of said transformer-circuits, for adjusting said circuits in electrical resonance with each other, substantially as described.

18. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a variable inductance being included in said open circuit, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and a variable inductance included in circuit with the wave-responsive device, substantially as described.

19. In a system of wireless telegraphy, the combination at a receiving-station, of an oscillation-transformer; an open circuit comprising, in part, an aerial conductor connected with one end of the primary coil of the oscillation-transformer; a connection from the other end of said coil to capacity; a variable inductance in said open circuit; and electrical connections from the secondary coil of the oscillation-transformer to a receiving instrument, battery, condenser, wave-responsive device and a variable inductance, substantially as and for the purpose described.

20. In a system of wireless telegraphy, a transmitting-station containing an oscillation-transformer, the primary of which is connected to a condenser-circuit discharging through a spark-gap which automatically causes electric waves of the desired frequency, the secondary of said transformer connected to an open circuit including a radiating-conductor, and with a capacity and a coil for charging the condenser aforesaid; a receiving-station containing an oscillation-transformer, the primary of which is connected with an oscillation-receiving conductor and with a capacity, a wave-responsive device connected with the secondary of said transformer, and a receiving instrument connected with the wave-responsive device, all in combination with means for bringing the four transformer-circuits, two at each station, into electrical resonance with each other, substantially as described.

GUGLIELMO MARCONI.

Witnesses:

R. B. Ransford,

G. F. Warren.

4083

~~ABANDONED~~

178. TELEGRAPHY
Wireless

Revived Mch 29, 1904

178.--~~TELEGRAPHY,~~
~~Telegraphs: Circuits & Systems.~~

1 9 0 0

C O N T E N T S:

Application papers.

1. Rej. Dec. 24, 1900.
2. Sub Spec July 3, 1901
3. Amendt A. July 3, 1901
4. Letter. Aug. 12, 1901
5. Amendt B. Dec. 9, 1901
6. Rej Feb. 11, 1902.
7. Amendt C & Aff. May 6, 1902
8. Rej June 3, 1902
9. Petition to Examiners and proposed Amendt D Oct. 12, 1903
9 1/2. Assoc. Power of Atty. Oct. 12, 1903
10. Examiner's Answer Oct 15, 1903.
11. Supp. Petition and proposed Amendt E Oct 24/03
12. Examiner's Ans. Oct. 26- 1903.
13. Brief for Marconi Nov. 4 1903
14. Commr's Decision Dec. 2- 1903.
15. Request for Oral Rehearing Feb 24, 1904
16. Brief on Rehearing March 3 1904
17. Commr's Decsn Mch 29 '04
18. Rej. Mar. 31- 1904.
19. Amendt F May 31, 1904
20.
21.
22.
23.

T I T L E:

Improvement in Apparatus for Wireless Telegraphy.

3689

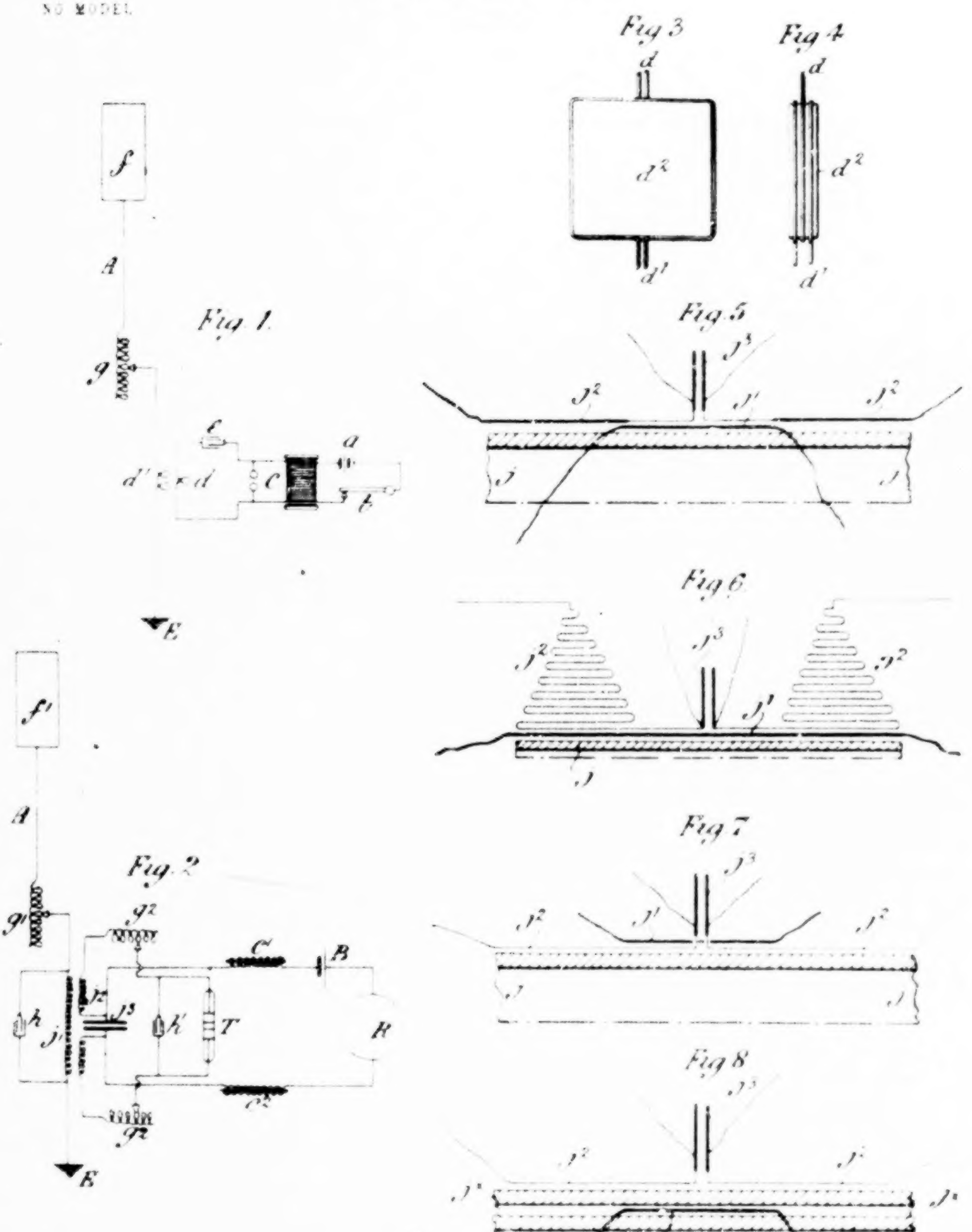
No. 763,772. PATENTED JUNE 28, 1904.

G. MARCONI.

APPARATUS FOR WIRELESS TELEGRAPHY.

APPLICATION FILED NOV. 10, 1900.

NO MODEL.



Witnesses

Inventor

GUGLIELMO MARCONI.

Betts Betts Sheffield & Betts

MARCONI

IN WIRELESS TELEGRAPHY

Witnesses:

A. M. Parkins

E. A. Bullock

Inventor

Guglielmo Marconi

By his Attorneys

Baldwin Davidson & Wight

3891-3892

UNITED STATES PATENT OFFICE.

GUGLIELMO MARCONI, OF LONDON, ENGLAND, ASSIGNOR TO THE WIRELESS TELEGRAPH AND SIGNAL COMPANY, LIMITED, OF SAME PLACE.

APPARATUS EMPLOYED IN WIRELESS TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 627,650, dated June 27, 1899.

Application filed January 5, 1899. Serial No. 701,251. (No model.)

To all whom it may concern:

Be it known that I, GUGLIELMO MARCONI, electrician, a subject of the King of Italy, residing at 28 Mark Lane, in the city of London, England, have invented certain new and useful Improvements in Apparatus Employed in Wireless Telegraphy, of which the following is a specification.

In the specification of a former patent granted to me, No. 586,193, I described a receiver in which the ends of an imperfect contact in a local circuit were connected one to earth and the other to an insulated conductor.

According to this invention the conductor is no longer insulated, but is connected to a capacity, which may be the earth, through the primary of an induction-coil, while the ends of the imperfect contact are connected to the ends of the secondary one of the connections, being through a condenser.

The induction-coil preferably consists of a few turns of insulated wire. Over or under this first winding, which constitutes the primary, is wound a secondary winding, which constitutes the secondary.

In order to obtain the best effects, it is essential that the induction-coil should be of very thin wire. It is desirable that the primary and secondary windings of the coil should be close to each other and that the windings of each should be in a single layer. It is desirable that the induction-coil should be in tune or syntony with the electrical oscillation transmitted, the most appropriate number of turns and most appropriate thickness of wire varying with the length of wave of the oscillation transmitted.

The capacity of the condenser on the connection between the imperfect contact and the secondary of the coil should be varied (in order to obtain best effects) if the length of wave is varied.

It is desirable that the conductor connected should offer a large surface, and therefore the use of such materials as broad wire-netting in lieu of wire is desirable. It is also desirable to employ thick conductors or netting or its equivalents at the transmitting end.

The introduction of the coil in the conductor not only improves the signals, but also prevents to a great extent any interference due to atmospheric influences, as any atmospheric electricity collected by the aerial conductor escapes to earth through the primary of the coil, thus preventing a charge from accumulating and discharging itself through the imperfect contact. Any stray interference can be further minimized by substituting a suitable capacity for the earth.

I have used a condenser of about one-fourth microfarad capacity for the above purpose.

Figure 1 is a diagram of the arrangement I prefer. Fig. 2 shows a modification. Fig. 3 shows the induction-coil.

In Fig. 1, A is a long conductor suspended in the air by insulators, and E is a connection to earth or other suitable capacity. B is a local battery, and R is a relay working a signaling or other instrument. j is the primary of the induction-coil or transformer, which is inserted between A and E. k is a condenser placed across the sensitive imperfect contact and the secondary winding of the induction-coil or transformer. c' c^2 are choking-coils, their object being to prevent the oscillations generated in the winding j^2 from running into the battery connections at b and d, which would weaken the effect of the oscillations on the sensitive imperfect contact T.

Fig. 2 shows a somewhat similar arrangement, which, however, does not give such good results as Fig. 1. In this case the condenser k is omitted.

I have obtained good results by employing an induction-coil or transformer constructed as follows: The primary j' of the said induction-coil or transformer is wound on a glass tube g about .635 centimeter in diameter. The said primary winding consists of two parallel windings of two hundred turns each of copper wire .012 centimeter in diameter insulated by a single covering of silk. The resistance of these two windings in parallel is about 3.1 ohms. The secondary winding j^2 of the induction-coil or transformer consists of about eight hundred turns of a similar but thinner wire .005 centimeter in di-

ameter wound over or under the primary winding. The resistance of the secondary winding is about one hundred and forty ohms.

The condenser k', which I preferably use, is composed of six tin-foil or copper plates connected to each terminal, each plate being five centimeters by three centimeters, the plates being insulated by paraffined paper .017 centimeter thick.

When using the above-described induction-coil or transformer, I employ as insulated conductor at each station a conductor formed of seven strands of about one-millimeter-diameter copper wire one hundred and forty feet long, the top of the conductor being one hundred and twenty feet from the ground. In some cases I use in lieu of the above-described conductor a galvanized-iron netting about two feet broad and one hundred and thirty feet long, the top of the netting being about one hundred and ten feet above the ground. In the latter case I obtain good results when using an induction-coil or transformer constituted as follows: secondary winding of three hundred and seventy-five turns of copper wire .005 centimeter in diameter insulated with one covering of silk, and wound on a glass tube .777 centimeter in diameter. Over this is wound the primary winding of one hundred and seventy-five turns of a similar wire .012 centimeter in diameter. The resistance of the primary winding is about 7.1 ohms and that of the secondary about 79 ohms.

What I claim is—

1. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, a local circuit through it, an induction-coil, a capacity, a conductor connected to one end of the primary of the coil, a connection between the other end and the capacity, connections between the ends of the imperfect contact and the ends of the secondary of the coil and a condenser in one of the latter connections.

2. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, a local circuit through it, a local battery and relay included in the local circuit, choking-coils respectively included in said circuit between the terminals of the imperfect electrical contact and the battery and relay, an induction-coil, a capacity, a conductor connected to one end of the primary of the coil, a connection between the other end and the capacity, connections between the ends of the imperfect contact and the ends of the secondary of the coil, and a condenser in one of the latter connections.

3. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, a local circuit through it, an induction-coil, the primary and secondary of which consist of a single layer only, a capacity, a conductor connected to one end of the primary of the coil, a connection between the other end and the capacity and connections between the ends of the imperfect contact and the ends of the secondary of the coil.

4. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, a local circuit through it, an induction-coil, the primary and secondary of which consist of a single layer only, a capacity, a conductor connected to one end of the primary of the coil, a connection between the other end and the capacity and connections between the ends of the imperfect contact, the ends of the secondary of the coil and a condenser in one of the latter connections.

5. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, a local circuit through it, an induction-coil, the primary and secondary of which consist of a single layer only, and in which the primary consists of a number of parallel wires connected at their ends, a capacity, a conductor connected to one end of the primary of the coil, a connection between the other end and the capacity and connections between the ends of the imperfect contact and the ends of the secondary of the coil.

6. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, a local circuit through it, an induction-coil, the primary and secondary of which consist of a single layer only, and in which the primary consists of a number of parallel wires connected at their ends, a capacity, a conductor connected to one end of the primary of the coil, a connection between the other end and the capacity and connections between the ends of the imperfect contact, the ends of the secondary of the coil and a condenser in one of the latter connections.

7. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, a local circuit through it, an induction-coil, the primary and secondary of which are both of wire not exceeding one-fiftieth of a centimeter in diameter, a capacity, a conductor connected to one end of the primary of the coil, a connection between the other end and the capacity and connections between the ends of the imperfect contact and the ends of the secondary of the coil.

8. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, a local circuit through it, an induction-coil, the primary and secondary of which are both of wire not exceeding one-fiftieth of a centimeter in diameter, a capacity, a conductor connected to one end of the primary of the coil, a connection between the other end and the capacity and connections between the ends of the imperfect contact, the ends of the secondary of the coil and a condenser in one of the latter connections.

GUGLIELMO MARCONI.

Witnesses:

ROBERT B. RANSFORD,
JOHN H. WHITEHEAD.

Defendants' Exhibit L-6

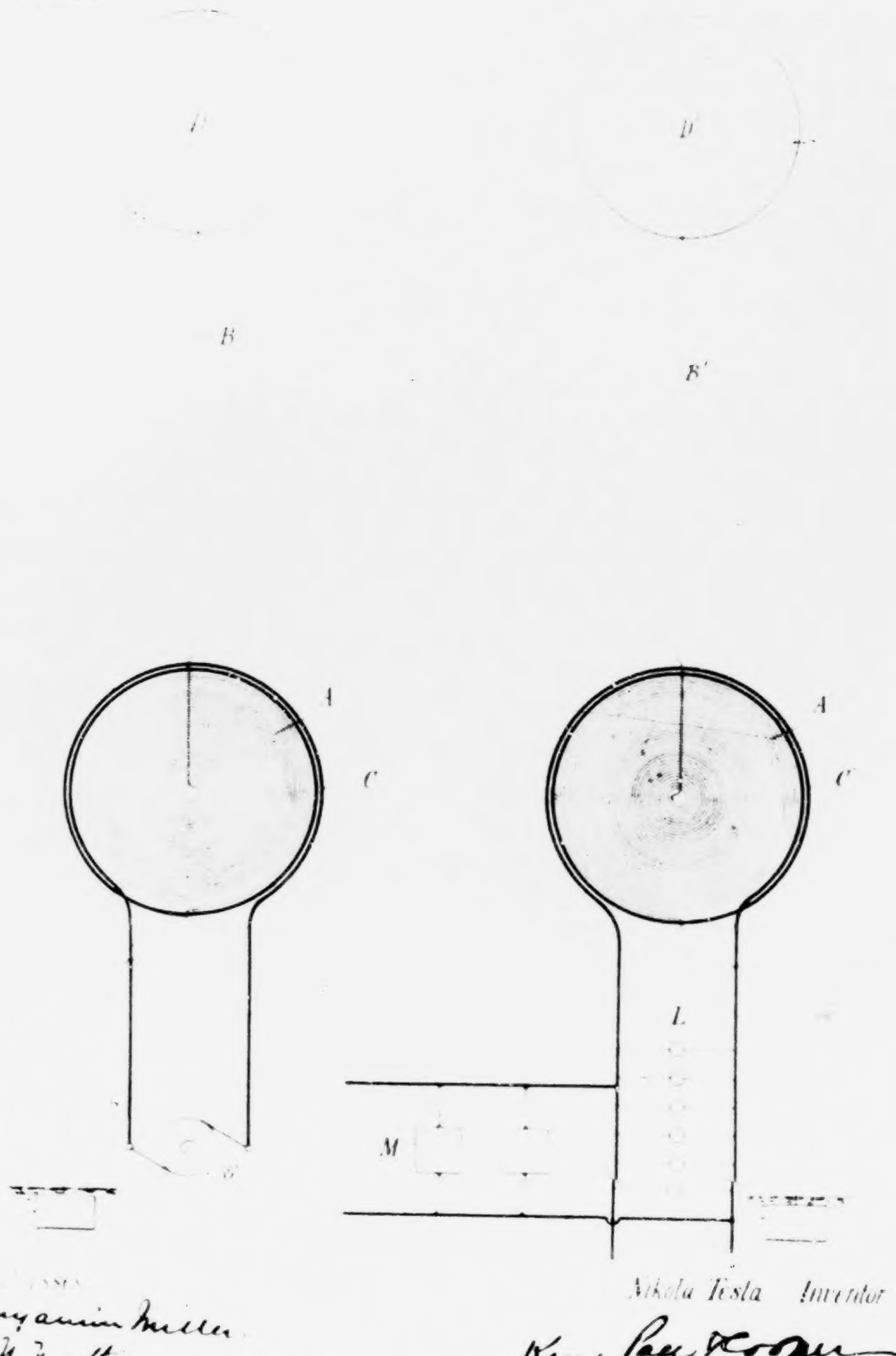
No. 649,621. Patented May 15, 1900.

N. TESLA.

APPARATUS FOR TRANSMISSION OF ELECTRICAL ENERGY.

Application filed Feb. 19, 1900.

No Model.



Witnesses:
Benjamin Miller
G. W. Martling

Nikola Tesla Inventor
by Kerr, Page & Cooper
Attys

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

APPARATUS FOR TRANSMISSION OF ELECTRICAL ENERGY.

SPECIFICATION forming part of Letters Patent No. 649,621, dated May 15, 1900.

Original application filed September 2, 1897, Serial No. 650,343. Divided and this application filed February 19, 1900. Serial No. 5,780. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at the borough of Manhattan, in the city of New York, county and State of New York, have invented certain new and useful Improvements in Apparatus for the Transmission of Electrical Energy, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

This application is a division of an application filed by me on September 2, 1897, Serial No. 650,343, entitled "Systems of transmissions of electrical energy," and is based upon new and useful features and combinations of apparatus shown and described in said application for carrying out the method therein disclosed and claimed.

The invention which forms the subject of my present application comprises a transmitting coil or conductor in which electrical currents or oscillations are produced and which is arranged to cause such currents or oscillations to be propagated by conduction through the natural medium from one point to another remote therefrom and a receiving coil or conductor at such distant point adapted to be excited by the oscillations or currents propagated from the transmitter.

This apparatus is shown in the accompanying drawing, which is a diagrammatic illustration of the same.

A is a coil, generally of many turns and of a very large diameter, wound in spiral form either about a magnetic core or not, as may be desired. C is a second coil formed by a conductor of much larger size and smaller length wound around and in proximity to the coil A.

The apparatus at one point is used as a transmitter, the coil A in this case constituting a high-tension, secondary, and the coil C the primary, of much lower tension, of a transformer. In the circuit of the primary C is included a suitable source of current G. One terminal of the secondary A is at the center of the spiral coil, and from this terminal the current is led by a conductor B to a terminal D, preferably of large surface, formed or maintained by such means as a balloon at an elevation suitable for the purposes of transmission. The other terminal of the secondary A is connected to earth, and, if desired, to the primary also, in order that the latter may be at substantially the same potential as the adjacent portions of the secondary, thus insuring safety. At the receiving-station a transformer of similar construction is employed; but in this case the longer coil A' constitutes the primary, and the shorter coil C' the secondary, of the transformer. In the circuit of the latter are connected lamps L, motors M, or other devices for utilizing the current. The elevated terminal D' connects with the center of the coil A', and the other terminal of said coil is connected to earth and preferably, also, to the coil C' for the reasons above stated.

The length of the thin wire coil in each transformer should be approximately one-quarter of the wave length of the electric disturbance in the circuit, this estimate being based on the velocity of propagation of the disturbance through the coil itself and the circuit with which it is designed to be used. By way of illustration, if the rate at which the current traverses the circuit including the coil be one hundred and eighty-five thousand miles per second then a frequency of nine hundred and twenty-five per second would maintain nine hundred and twenty-five stationary moves in a circuit one hundred and eighty-five thousand miles long and each wave would be two hundred miles in length.

For such a low frequency, which would be resorted to only when it is indispensable for the operation of motors of the ordinary kind under the conditions above assumed, I would use a secondary of fifty miles in length. By such an adjustment or proportioning of the length of wire in the secondary coil or coils the points of highest potential are made to coincide with the elevated terminals D D', and it should be understood that whatever length be given to the wires this requirement should be complied with in order to obtain the best results.

It will be readily understood that when the above-prescribed relations exist the best conditions for resonance between the transmit-

ting and receiving circuits are attained, and owing to the fact that the points of highest potential in the coils or conductors A A' are coincident with the elevated terminals the maximum flow of current will take place in the two coils, and this, further, necessarily implies that the capacity and inductance in each of the circuits have such values as to secure the most perfect condition of synchronism with the impressed oscillations.

When the source of current G is in operation and produces rapidly pulsating or oscillating currents in the circuit of coil C, corresponding induced currents of very much higher potential are generated in the secondary coil A, and since the potential in the same gradually increases with the number of turns toward the center and the difference of potential between the adjacent turns is comparatively small a very high potential impracticable with ordinary coils may be successively obtained.

As the main object for which the apparatus is designed is to produce a current of excessively-high potential, this object is facilitated by using a primary current of very considerable frequency; but the frequency of the currents is in a large measure arbitrary, for if the potential be sufficiently high and the terminals of the coils be maintained at the proper elevation where the atmosphere is rarefied the stratum of air will serve as a conducting medium for the current produced and the latter will be transmitted through the air, with, it may be, even less resistance than through an ordinary conductor.

As to the elevation of the terminals D D', it is obvious that this is a matter which will be determined by a number of things, as by the amount and quality of the work to be performed, by the condition of the atmosphere, and also by the character of the surrounding country. Thus if there be high mountains in the vicinity the terminals should be at a greater height, and generally they should always be at an altitude much greater than that of the highest objects near them. Since by the means described practically any potential that is desired may be produced, the currents through the air strata may be very small, thus reducing the loss in the air.

The apparatus at the receiving-station responds to the currents propagated from the transmitter in a manner which will be well understood from the foregoing description. The primary circuit of the receiver—that is, the thin wire coil A'—is excited by the currents propagated by conduction through the intervening natural medium from the transmitter, and these currents induce in the secondary coil C' other currents which are utilized for operating the devices included in the circuit thereof.

Obviously the receiving-coils, transformers, or other apparatus may be movable—as, for instance, when they are carried by a vessel floating in the air or by a ship at sea. In the former case the connection of one terminal of the receiving apparatus to the ground might not be permanent, but might be intermittently or inductively established without departing from the spirit of my invention.

It is to be noted that the phenomenon here involved in the transmission of electrical energy is one of true conduction and is not to be confounded with the phenomena of electrical radiation which have heretofore been observed and which from the very nature and mode of propagation would render practically impossible the transmission of any appreciable amount of energy to such distances as are of practical importance.

What I now claim as my invention is—

1. The combination with a transmitting coil or conductor connected to ground and to an elevated terminal respectively, and means for producing therein electrical currents or oscillations, of a receiving coil or conductor similarly connected to ground and to an elevated terminal, at a distance from the transmitting-coil and adapted to be excited by currents caused to be propagated from the same by conduction through the intervening natural medium, a secondary conductor in inductive relation to the receiving-conductor and devices for utilizing the current in the circuit of said secondary conductor, as set forth.

2. The combination with a transmitting coil or conductor having its ends connected to ground and to an elevated terminal respectively, a primary coil in inductive relation thereto and a source of electrical oscillations in said primary circuit, of a receiving conductor or coil having its ends connected to ground and to an elevated terminal respectively and adapted to be excited by currents caused to be propagated from the transmitter through the natural medium and a secondary circuit in inductive relation to the receiving-circuit and receiving devices connected therewith, as set forth.

3. The combination with a transmitting instrument comprising a transformer having its secondary connected to ground and to an elevated terminal respectively, and means for impressing electrical oscillations upon its primary, of a receiving instrument comprising a transformer having its primary similarly connected to ground and to an elevated terminal, and a translating device connected with its secondary, the capacity and inductance of the two transformers having such values as to secure synchronism with the impressed oscillations, as set forth.

4. The combination with a transmitting instrument comprising an electrical transformer having its secondary connected to ground and to an elevated terminal respectively, and means for impressing electrical oscillations upon its primary, of a receiving instrument comprising a transformer having its primary similarly connected to ground and to an elevated terminal, and a translat-

ing device connected with its secondary, the capacity and inductance of the secondary of the transmitting and primary of the receiving instruments having such values as to secure synchronism with the impressed oscillations, as set forth.

5. The combination with a transmitting coil or conductor connected to ground and an elevated terminal respectively, and means for producing electrical currents or oscillations in the same, of a receiving coil or conductor similarly connected to ground and to an elevated terminal and synchronized with the transmitting coil or conductor, as set forth.

6. The combination with a transmitting instrument comprising an electrical transformer, having its secondary connected to ground and to an elevated terminal respectively, of a receiving instrument comprising a transformer, having its primary similarly connected to ground and to an elevated terminal, the receiving-coil being synchronized with that of the transmitter, as set forth.

7. The combination with a transmitting coil or conductor connected to ground and to an elevated terminal respectively, and means for producing electrical currents or oscillations in the same, of a receiving coil or conductor similarly connected to ground and to an elevated terminal, the said coil or coils having a length equal to one-quarter of the wave length of the disturbance propagated, as set forth.

8. The combination with a transmitting coil or conductor connected to ground and to an elevated terminal respectively, and adapted to cause the propagation of currents or oscillations by conduction through the natural medium, of a receiving-circuit similarly connected to ground and to an elevated terminal, and of a capacity and inductance such that its period of vibration is the same as that of the transmitter, as set forth.

9. The transmitting or receiving circuit herein described, connected to ground and an elevated terminal respectively, and arranged in such manner that the elevated terminal is charged to the maximum potential developed in the circuit, as set forth.

10. The combination with a transmitting coil or conductor connected to ground and to an elevated terminal respectively of a receiving-circuit having a period of vibration corresponding to that of the transmitting-circuit and similarly connected to ground and to an elevated terminal and so arranged that the elevated terminal is charged to the highest potential developed in the circuit, as set forth.

NIKOLA TESLA.

Witnesses:
PARKER W. PAGE,
MARCELLUS BAILEY.

DEFENDANT'S EXHIBIT M-6 4093

No. 797,169. PATENTED AUG. 15, 1905.

F. BRAUN.

SPACE TELEGRAPHY.

APPLICATION FILED FEB. 6, 1899.

Fig. 1

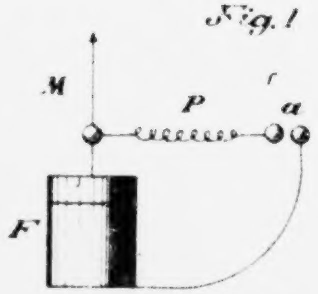
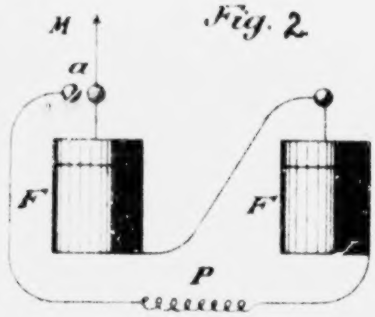


Fig. 2



Attest

Inventor

Ferdinand Braun

By

Attys

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UNITED STATES PATENT OFFICE.

FERDINAND BRAUN, OF STRASSBURG, GERMANY.

SPACE TELEGRAPHY.

No. 797,169. Specification of Letters Patent. Patented Aug. 15, 1905.

Application filed February 6, 1899. Serial No. 04,605.

To all whom it may concern:

Be it known that I, FERDINAND BRAUN, a subject of the German Emperor, and a resident of Strassburg, Alsace, German Empire, have invented a new and useful Improvement in Space Telegraphy, of which the following is a specification.

My invention relates to the transmission of electric signals without connecting-wires and comprises the improvements hereinafter described.

Electrical vibrations, although similar in their physical nature, may be classified for practical purposes into three groups. The first group includes vibrations which are created by the relative mechanical movements of magnets, coils, wires and so on. These are exemplified in the well-known ordinary alternating currents, as used for electric light and transmission of power. Their frequency will obviously be limited by the physical conditions of machinery.

A second group of electrical vibrations consists of oscillations which are produced by the discharge of Leyden jars, or condensers, with or without inductance-coils in circuit. The frequency of these oscillations, which is considerably higher than the frequency of the former group, can be calculated by well-known relations between capacity and inductance.

A third group of vibrations or oscillations is that first studied experimentally by the late Dr. Hertz, and in the production of these the capacity and inductance are not obtained by means of specially-provided Leyden jars, or condensers, and inductance-coils, but the capacity and inductance of ordinary conductors are used.

Hitherto the attention of inventors, occupied with the transmission of signals without the use of connecting-wires, by means of Hertzian or electromagnetic ether waves, has been principally confined to the use of such waves produced by the oscillations of the last-mentioned group, and one object has been to increase the frequency of these waves as much as possible. This is exemplified by the use of the Righi transmitter. For the transmission of such short waves it is essential, however, that the transmitting and receiving stations should be, so to speak, visible to each other; as stated by Hertz in one of his earlier papers concerning the transmission of electromagnetic ether waves and by subsequent experiments, it has been shown, that various material objects, such as sails, smoke, trees, buildings and the like, interposed between the two stations, weaken or in some cases entirely prevent communication between them. My invention is intended to obviate this inconvenience and I do this by making use of electrical oscillations belonging to the second group above mentioned which have only a small frequency compared with the frequency of the oscillations of the third group. By this means, owing to the greater length of the waves produced, these latter are able to pass through conductors if these are but of moderate thickness. Furthermore, obstacles in the path of waves will not project such sharply-defined shadows, the waves passing around them in a manner similar to that which sound-waves pass round obstacles. Another advantage in using slower vibrations or oscillations is that their potential and amplitude, and thereby the energy transmitted, are more easily increased. When the higher-frequency waves are used, produced by the oscillations of the third group above mentioned, there is a certain length of spark which must not be exceeded if the circuit is required to excite vibrations or oscillations; otherwise the vibrations or oscillations would be damped too much; but this means that the effective potential is limited, which, if oscillations of the second group are used either does not occur, or can be very easily avoided.

I have found by experiments that the oscillations produced by the discharge of Leyden jars of usual size in a circuit having moderate inductance, are very convenient for the purpose of transmitting signals.

In carrying out my invention, I make use of the well-known upwardly-projecting transmitting-wire, and receiving-wire connected to the coherer in the receiving-station. It is well understood in the art that the function of the former wire, which projects upwardly and to a considerable height, is to spread out or radiate the electromagnetic ether waves through the air, and of the latter wire to collect these waves and to convey them to the coherer.

As the object of my invention is to use the waves created by the oscillations produced by the discharge of Leyden jars or other condensers, it is essential for my invention that the transmitting-wire be so related to the oscillation-circuit containing the Leyden jars that oscillations will be created in the transmitting-wire by the oscillations in said circuit. For this purpose the transmitting-wire

is in accordance with the present invention connected conductively to the oscillation-circuit, as illustrated diagrammatically in the drawings.

A form of apparatus in which the transmitting-wire is not conductively connected to the oscillation-circuit but is inductively connected thereto is described and claimed in my application Serial No. 157,728, filed May 18, 1903, as a division of this application.

An oscillation-circuit comprising a Leyden jar or condenser and spark-gap, with or without an inductance-coil, is, and for a long time has been, well known to be a persistently-oscillating circuit, or a circuit in which its electrical equilibrium having once been disturbed, vibrations or oscillations continue for a considerable length of time. In other words, this circuit is a source of maintained or sustained electrical oscillations. This circuit I have likened to a "reservoir of energy," a portion of which is radiated from the transmitting-wire for every oscillation until there is no more energy left and the circuit ceases to vibrate.

In order that my invention may be clearly understood, I have shown in the accompanying drawings by way of example, some arrangements of circuits for transmitting signals by means of the electric oscillations above described.

Figure 1 illustrates diagrammatically a transmitting apparatus constructed in accordance with the invention. Fig. 2 shows a modified arrangement of the same.

In Fig. 1 a Leyden jar indicated at F has its inner and outer coatings connected through the spark-gap *a*, a coil P of small self induction or inductance being included in the oscillation-circuit which increases the normal inductance of such circuit. The inner coating is connected to the transmitting-wire M. It is well understood that the transmitting-wire may be of any suitable size. The jar is charged in the usual manner by means of an influence-machine, inductorium or other suitable means.

In place of one jar, two or more can be used connected in parallel or series. Fig. 2 for example shows two jars arranged in series, or as commonly called in "cascade."

The invention is not limited to the precise arrangements of circuits shown in the drawings, as these can be varied very considerably, and electric oscillations of low frequency suitable for transmitting signals according to my invention can be produced in various other ways.

Leyden jars have been used heretofore in connection with wireless telegraphy, but never before have the oscillation-circuits been conductively connected to the transmitting-wires so that the oscillations in said circuits create oscillations in the transmitting-wires which latter create and cause to radiate therefrom electromagnetic ether waves.

What I claim is—

1. In a transmitter for wireless telegraphy, the combination with an oscillation-circuit containing a condenser, of a transmitting-wire connected conductively with said circuit, substantially as and for the purpose stated.

2. In a transmitter for wireless telegraphy, the combination with an oscillation-circuit containing a condenser and a spark-gap, of a transmitting-wire connected conductively with said circuit, substantially as and for the purpose stated.

3. In a transmitter for wireless telegraphy, the combination with an oscillation-circuit containing a condenser and an inductance means for increasing the normal inductance of said circuit, of a transmitting-wire connected conductively with said circuit, substantially as and for the purpose stated.

4. In a transmitter for wireless telegraphy, the combination with an oscillation-circuit containing a condenser and a spark-gap and an inductance means for increasing the normal inductance of said circuit, of a transmitting-wire connected conductively with said circuit, substantially as and for the purpose stated.

5. In a transmitter for wireless telegraphy, a transmitting-wire provided with a spark-gap, a condenser connected across the spark-gap, and a source of electrical energy connected to the terminals of the spark-gap.

6. In a transmitter for wireless telegraphy, a transmitting-wire provided with a spark-gap, a condenser connected across the spark-gap, and a source of periodically-varying electromotive force connected to the terminals of the spark-gap.

7. In a transmitter for wireless telegraphy, a transmitting-wire provided with a spark-gap, a plurality of condensers connected across the spark-gap, and a source of periodically-varying electromotive force connected to the terminals of the spark-gap.

8. In a transmitter for wireless telegraphy, a transmitting-wire connected conductively with a closed oscillation-circuit.

9. In a transmitter for wireless telegraphy, a transmitting-wire connected conductively with a persistently-oscillating circuit.

10. In a system of wireless telegraphy, a transmitting-wire connected conductively with a source of persistent electrical oscillations.

11. In a system of wireless telegraphy, means for radiating electromagnetic waves of low frequency, comprising a transmitting-wire conductively connected with a source of persistent low-frequency electric oscillations.

In testimony whereof I have hereunto set my hand in presence of two subscribing witnesses.

FERDINAND BRAUN.

Witnesses:

FRITZ NIESS,

MAX ADLER.

DEFENDANT'S EXHIBIT N-6

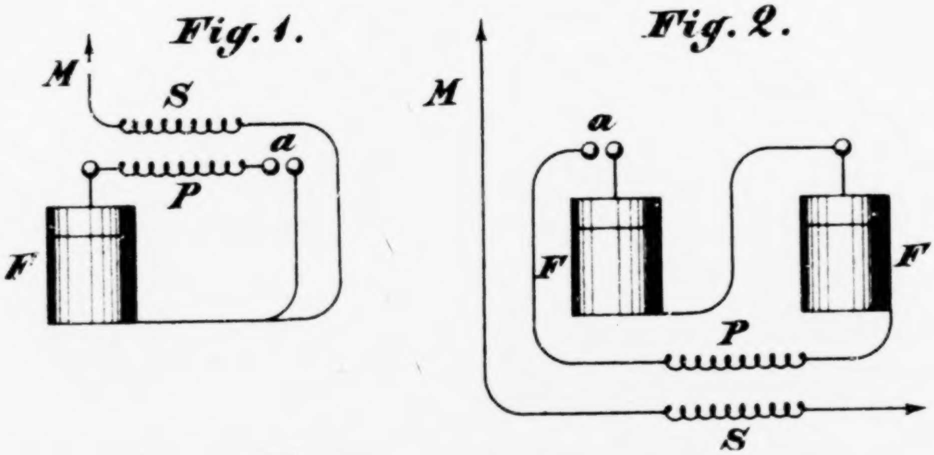
No. 797,544.

PATENTED AUG. 15, 1905.

F. BRAUN.

SPACE TELEGRAPHY.

APPLICATION FILED MAY 18, 1903.



Witnesses
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UNITED STATES PATENT OFFICE.

FERDINAND BRAUN, OF STRASSBURG, GERMANY.

SPACE TELEGRAPHY.

No. 797,544. Specification of Letters Patent. Patented Aug. 15, 1905.

Original application filed February 6, 1899, Serial No. 704,605. Divided and this application filed May 18, 1903. Serial No. 157,728.

To all whom it may concern:

Be it known that I, FERDINAND BRAUN, a subject of the German Emperor, and a resident of Strassburg, Alsace, German Empire, have invented a new and useful Improvement in Space Telegraphy, of which the following is a specification.

My invention relates to the transmission of electric signals without connecting-wires and comprises the improvements hereinafter described.

The invention is a part of that for which an application, Serial No. 704,605, was filed by me February 6, 1899. In said application the advantage is shown which is arrived at by using Hertzian or electromagnetic ether-waves of lower frequency than the Hertzian and Righi waves mainly used before, and said application shows and describes the use of oscillations produced by the discharge of a Leyden jar or condenser with or without an inductance-coil in the oscillation-circuit, and a transmitting-wire conductively connected to the oscillation-circuit so that oscillations in said circuit create oscillations in the transmitting-wire, which latter create and cause to radiate therefrom electromagnetic ether-waves. This divisional application relates to apparatus in which the transmitting-wire is inductively connected with the oscillation-circuit.

An oscillation-circuit comprising a Leyden jar or condenser and spark-gap, with or without an inductance-coil, is, and for a long time has been, well known to be a persistently-oscillating circuit, or a circuit in which, its electrical equilibrium having once been disturbed, vibrations or oscillations continue for a considerable length of time. In other words, this circuit is a source of maintained or sustained electrical oscillations. This circuit I have likened to a "reservoir of energy," a portion of which is radiated from the transmitting-wire for every oscillation until there is no more energy left and the circuit ceases to vibrate.

The invention is illustrated by the accompanying drawings by way of example.

Figure 1 shows diagrammatically a transmitting apparatus according to the present invention. Fig 2 illustrates a modification thereof.

In Fig. 1, F is a Leyden jar preferably of the usual size. An oscillation-circuit is provided containing said Leyden jar F, an air-gap *a* and the primary P of a suitable transformer, which primary coil will also act as an inductance-coil. One end of the secondary S of this transformer is connected to any point of the oscillation-circuit, as for example between the air-gap and the outer coating of the Leyden jar, and the other end to the upwardly-extending transmitting-wire M. By dimensioning properly the Leyden jars, the transformers, the coils &c. the most favorable results will be obtained.

In Fig. 2 an oscillation-circuit is provided containing two Leyden jars connected in series for reducing the capacity, and a primary coil P of a transformer, which also acts as an inductance-coil. One end of the secondary coil of the transformer S is connected with the transmitting-wire M, and the other end is shown prolonged and ending in an arrow to indicate that it may be prolonged by adding a suitable length of insulated wire or connected to some other suitable capacity area.

The use of the electric connection by means of a transformer between the oscillation-circuit and the transmitting-wire enables the potential to be obtained which is most fit for the production of electromagnetic waves. Experience has shown that transformed oscillations are very useful. Experience has shown also that the action of oscillating energy can be essentially increased by the invention, so that it is possible to overcome longer distances than it has been before.

The invention is not limited to the precise arrangements of circuits shown in the drawings, as these can be varied considerably. Therefore I do not limit myself to the particular arrangements shown, but

What I claim is—

1. In a transmitter for wireless telegraphy, the combination with an oscillation-circuit containing a condenser and the primary of a transformer, of a transmitting-wire connected with the secondary of the transformer, the other end of said secondary being connected to one plate of said condenser.

2. In a transmitter for wireless telegraphy, the combination with an oscillation-circuit

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containing a condenser and the primary of a transformer, of a transmitting-wire connected with the secondary of the transformer, the other end of said secondary being connected to a capacity area other than earth and having no direct connection with earth.

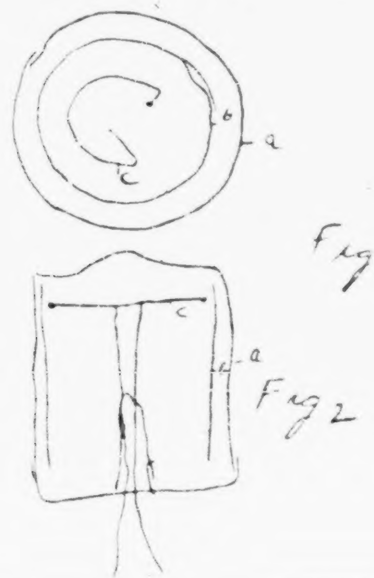
In testimony whereof I have hereunto set my hand in presence of two subscribing witnesses.

FERDINAND BRAUN.

Witnesses:
JONATHAN TRESNECK,
STEVEN BRANDER.

DEFENDANT'S EXHIBIT Q-6

Sketch made by Weagant at R. 1542



DEFENDANT'S EXHIBIT S-6

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another instance of what was well known, the enormous use that medical skill and science was in promoting sympathetic relations between Europeans and Orientals. A medical man could set aside politics and religion, and establish himself in communication with the people of the country in a way which no one else could. It was a remarkable fact that they should be that evening in the centre of London, listening with interest to an account of a wild country in the centre of Asia. Could there be a stronger instance of the immense width of the English dominion and English interests? We had very strong interests in Afghanistan; it was not exactly within our frontiers; but its frontiers we had undertaken to protect, the line having been laid down by agreement between the two great European powers, which were both making for themselves empires in Asia—England and Russia. It was for that reason that those who sat at home, safe behind their sea-washed barriers, were responsible for the maintenance of the frontier, and the welfare of people at such a distance. There was no doubt the Amir was one of the most powerful and successful monarchs, perhaps, in Asia, and his was one of those curious kingdoms which had been left standing, notwithstanding the agglomerations of the great empires of Russia, China, Persia, and India. The people of Afghanistan were an agglomeration of tribes, but beyond that they were an assemblage of free men who, like ourselves, considered liberty one of the noblest gifts. They had always fought gallantly against the foreigner, and were determined, if possible, to have their country for themselves. We could all sympathise with people of that sort, and for that reason he cordially echoed the wish the Chairman had expressed that we should use every exertion to preserve the liberties of the Afghan people, and maintain its independence and integrity.

Colonel E. T. Thackeray, R.E., C.B., V.C., said, one interesting feature of Afghanistan was the system of subterranean canals, or underground channels, which were made for connecting together the shafts sunk wherever water was expected to be found. Some of these canals were carried to a length of about 20 miles. These canals were supposed to have been originated by King Hushung, who was also supposed to have built the seven great cities of Afghanistan, besides Kabul. Earthquakes were extremely common in that country.

A vote of thanks to Mr. Gray for his interesting paper was carried unanimously, and briefly acknowledged.

FOREIGN & COLONIAL SECTION.

Tuesday, February 20, 1894; Sir Albert Kaye Rollit, LL.D., M.P., Vice-President of the Society, in the chair.

The paper read was "The Arts and Industries of Belgium, and the Antwerp Exhibition, 1894," by Edouard Seve.

The paper and discussion will be printed in the next number of the *Journal*.

TWELFTH ORDINARY MEETING.

Wednesday, Feb. 21, 1894; Sir Richard Webster, Q.C., M.P., Chairman of the Council, in the chair.

The following candidates were proposed for election as members of the Society:—

Kent, Walter G., 199, High Holborn, W.C.
Niven, David Coats, Oriental Gas Company, Calcutta.
Walker, Ernest Octavius, C.I.E., Brook-hill-house, Teignmouth, Devon.
Walton, Joseph, Zetland-buildings, Middlesbrough.
Williamson, G. H., Mayor of Worcester

The following candidate was balloted for and duly elected a member of the Society:—

Bruff, Charles Clarke, Coalport, Shropshire.

The paper read was—

ELECTRIC SIGNALLING WITHOUT WIRES.

By W. H. Preece, C.B., F.R.S.

What is electricity? Few venture to reply boldly to this question, first, because they do not know; secondly, because they do not agree with their neighbours, even if they think they know; thirdly, because their neighbours do not agree among themselves, even as to what to apply the term. The physicist applies it to one thing, the engineer to another. The former regards his electricity as a form of ether, the latter as a form of energy. I cannot grasp the concept of the physicist, but electricity as a form of energy is to me a concrete fact. The electricity of the engineer is something that is generated and supplied, transformed and utilised, economised and wasted, meted out and paid for. It produces motion of matter, heat, light, chemical decomposition, and sound; while these effects are reversible, sound, chemical decomposition, light, heat, and motion reproduce those effects which are called electricity.

Faraday's immortal researches, Clerk-Maxwell's prophetic investigations, and Hertz's convincing experiments, have definitely and conclusively proved the existence of one medium throughout all space, called the

ether, through which waves of energy, called radiations, are propagated with the same velocity, but in different forms and with different frequencies, although all of the same character. At one end of the scale we have actinic disturbances producing photographic impressions; at the other end of the scale electric waves producing electromagnetic disturbances while the intermediate radiations give light and heat. Actinic waves are extremely minute and number many millions per second, electric waves are very long and may number only hundreds per second. Like light waves, they are propagated in straight lines, they obey the laws of reflection, they are refracted, they are subject to interference, and they may be even polarised.

We have to consider electric waves to-night, and I want to show you how we are gradually, by patient plodding, creeping along towards the period when I hope we shall be able to make real practical use of such electromagnetic disturbances.

If we take a conductor through which a rapidly alternating current is being supported by any means, it throws the ether which surrounds it into oscillations. Energy is thus radiated away in electric waves. These electric waves spread out in all directions, as do waves of light, and if they fall on similar conductors properly placed and sympathetically prepared, these waves of energy are transformed back again into alternating currents which give evidence of their presence. Their presence is indicated by a telephone if the frequency of the alternating currents is brought within the range of the ear. Hertz and his followers experimented with waves of much shorter length, and with sparks in air, but all my experiments have been made with telephones and with waves comparable in frequency with those of sound.

The prime source of energy has been either a steam-engine or a galvanic battery. This has produced, by suitable machinery, rapidly intermittent or alternating currents, which have been transmitted through a primary circuit. At some distance away from this circuit there has been a secondary telephone circuit, and between these two circuits the only connecting medium has been the ether, which has been thrown into electric oscillation, and it has been across this space that I have been signalling without wires. In all cases, the primary currents were of such a frequency as to produce a musical note in the telephones fixed in the secondary circuit, which could easily be read, if sent in the dots and dashes of the Morse code.

Signalling through space is very fascinating. I have now for ten years been steadily investigating the subject. In 1884, messages sent through insulated wires, buried in iron pipes in the streets of London, were read upon telephone circuits erected on poles 80 feet away on the housetops. It was imagined this must have been due to accidental connections, or to earths, or to any other cause but the true one, namely, electromagnetic induction, or the influence which one conductor conveying currents exercises on another parallel to it, when separated by a dielectric, or by mere space, that is, by the ether.

It is very difficult to convert the human mind from one mode of thought to another. We have been so trained to regard currents of electricity as something flowing in one complete unbroken circuit, that their temporary condition as waves of energy in space is difficult to realise. One irresistibly endeavours to trace them to earth conduction, to leakage, to contact, or to some more well-known cause. Ten years of unremitting experiment have, however, proved the effects I am bringing before you to be due, primarily, to radiation, and not to conduction.

In 1885, a very exhaustive series of experiments was made for me by Mr. A. W. Heaviside, in the neighbourhood of Newcastle, to find out how far the distance between the wires affected the results. Ordinary telegraph working currents produced disturbances at a distance of 2,000 feet, while effects on parallel lines of telegraph, 10½ miles apart, between Durham and Darlington, were perceptible. Distinct speech was carried on through a distance of one quarter of a mile. We even obtained indications of current between the east and west coasts, 40 miles apart, but these observations were vitiated by conduction through the large network of telegraph wires between those two places. I brought the subject before the British Association at their meeting in Birmingham in 1886. The district between Gloucester and Bristol, along the banks of the River Severn, was then selected, where for a length of 14 miles, and at an average distance apart of 4·5 miles, no intermediate disturbing conductors existed. I was able to experiment with complete metallic circuits, the return wires passing far inland, in the one case through Monmouth, and, in the other, through Stroud. Weak disturbances were detected. These experiments

were repeated, with more experience and greater success, in 1889. Similar experiments were conducted along the valley of the Mersey. A new trunk line of copper wires that was being erected between London and the coast of North Wales was then experimented upon, and some interesting results were obtained in the district between Shrewsbury and Much Wenlock, and between Worcester and Bewdley.

An admirable series of experiments were made for me in the same year, by Mr. Gavey near Porthcawl, in South Wales. There we have a wide expanse of sand well covered by the tide and giving the opportunity to observe the effects in water as well as in air. Squares of insulated wire, 1,200 yards long, were laid side by side at various distances apart, and smaller squares were suspended above each other on scaffold poles. The effects were observable equally in air and water. The results were absolutely conclusive that we were working with the so-called electro-magnetic induction, and all subsequent experience has confirmed this conclusion.

These further experiments were brought before the British Association at Manchester in 1887.

Thus the theory of the thing had been thoroughly threshed out, and it only waited for some convenient opportunity to give it a practical test.

When the Royal Commission to inquire into electric communication between the shore and lighthouses and light vessels was appointed in June, 1892, the question was started. Here was the opportunity. My proposal to test this means of communication in a practical way was submitted by the Postmaster-General to the Treasury. The expenditure was sanctioned, and the experiment made. The results were submitted by me to the Electric Congress which was held in Chicago in August in 1893.

The Bristol Channel proved a very convenient locality to test the practicability of communicating across a distance of three and five miles. Two islands, the Flat Holm and the Steep Holm, lie off Penarth and Lavernock Point, near Cardiff, the former having a lighthouse upon it. On the shore two copper wires weighing 400 lbs. per mile, forming one conductor, were suspended on poles for a distance of 1,267 yards, the circuit being completed by the earth. Experience justified the assumption that the earth acts as a conductor, and that it practically replaces the fourth side of the rectangle used in the previous experiments. We have not yet determined the actual position of the resultant line of this earth side, but further experiments are being made. On the sands at low water mark, 600 yard from this primary circuit and parallel to it, two ordinary gutta-percha covered copper wires and one bare copper wire were laid down, their ends being buried deep in the ground by means of bars driven in the sand.

One of the gutta-percha wires was lashed to an iron wire to represent a cable. These wires were periodically covered by the tide which rises here at springs to 33 feet. On the Flat Holm, 3·1 miles away, another gutta-percha covered copper wire was laid for a length of 600 yards.

There was also a small steam launch having on board several lengths of gutta-percha covered wire. One end of such a cable, half a mile long, was attached to a small buoy, which acted as a kind of float to the end, keeping the wire suspended upon or near the surface of the water while the launch slowly steamed ahead against the tide. It was paid out and picked up in several positions between the primary circuit and the islands.

The apparatus used on shore was a 2 horse-power portable Marshall's steam-engine, working a Pike and Harris's alternator, sending 192 complete alternations per second at a voltage of 150, and of any desirable strength up to a maximum of 15 ampères. These alternating currents were broken up into Morse signals by a suitable key and sent along the primary circuit. The signals received on the secondary circuit produced sound and were read on a pair of telephones—the same instruments being used for all the experiments.

The object of the experiments was not only to test the practicability of signalling between the shore and the lighthouse, but to differentiate the effects due to earth conduction from those due to electromagnetic induction, and to determine the effects in water.

It was possible to trace, without any difficulty, the region where the signals ceased to be perceptible from currents, due to earth conduction, and where they commenced to be solely due to electric waves. This was found by allowing the paid-out cable, suspended near the surface of the water, to sink. Near the shore, no difference was perceptible, whether the cable was near the surface or lying on the bottom, but a point was reached where all sounds ceased as the cable sank, but were recovered again when the cable came to the surface.

The total absence of sound in the submerged cable rather surprised me, and it leads to the conclusion, either that the waves of energy are dissipated in the sea water, or else that they are reflected away from the surface of the water like rays of light. I believe implicitly in the latter explanation. Subsequently, experiments on the sands in the Conway Estuary showing the relative transparency of air and water to these electric waves, tend to support the latter deduction, for if waste of energy took place in the water, the difference would be more marked than was actually found to be the case. It was 6 per cent. only. As it is, we have ample evidence that the electric waves are transmitted to considerable distances through water, though how far remains to be found out.

There was no difficulty in communicating between the shore and Flat Holm. Messages were read. Mr. Gavey, who was making the experiment on the island, wrote me, "There was then a somewhat lengthened pause, due to a slight derangement of the machinery on the mainland, but at 2 p.m. I heard clearly and distinctly the following, 'Here Haskayne' (one of his assistants) 'with a message from Mr. Preece for Mr. Gavey.'" I was in London that day. "Then followed the announcement of the sad and sudden death of Mr. Graves, which cast a gloom over the success of the experiment. It seemed an extraordinary fact, that the first readable message transmitted for such a distance by such means should announce the death of the head of the Technical Department."

The distance between the two places was 3·1 miles. The attempt to speak between Lavernock and Steep Holm was not so successful. The distance was 5·35 miles, but though signals were perceptible, conversation was impossible. There was distinct evidence of sound, but it was impossible to differentiate the sounds into Morse signals. We were just on the limit of audibility, and we were using our available maximum power. If either line had been longer, or the primary currents stronger, we should have spoken as was done at Flat Holm.

As the laws governing these effects were by no means so clear and conclusive as such probing and enquiring deserved, Mr. Gavey and Mr. Kempe conducted for me a very careful series of experiments near Frodsham, on the estuary of the Dee, which was found to be a more convenient locality than Conway, and the very satisfactory results obtained will shortly be published. The conditions are now so clear that, given the locality [illegible] which it is desired to communicate, it is a mere matter of calculation to show what has to be done. It would be quite easy to speak between France and England across the Straits of Dover.

There happens to be a very convenient and accessible loch in the highlands—Loch Ness—forming part of the route of the Caledonian Canal between Inverness and Bannavie, having a line of telegraph on each side of it. Two wires on each side of this loch were taken and so arranged that any fractional length of telegraph wire on either side could be taken for trial. Ordinary, and not special apparatus was employed, sending messages, as before, by Morse signals, and speaking by telephone across a space of one and a quarter miles was found practical, and, in fact, easy; indeed, the sounds were so loud, that they were found sufficient to form a call for attention.

The following apparatus was in use on each side of the loch for the transmission of Morse signals:—A set of batteries consisting of [illegible] dry cells, giving a maximum voltage of [illegible]; a rapidly revolving rheotome which broke up the current into a musical note; a Morse key, by which these musical notes could be transformed into Morse signals; resistance coils and ampères meters to vary the primary current; two Bell telephones joined in multiple arc to act as receivers. For the transmission of actual speech simple granular carbon microphones, known as the Deckert's, were used as transmitters, and a current of 2 ampères was maintained through these and two Bell telephones in circuit with the line wire.

Any lingering fear that earth conduction had principally to do with these results was removed by making the earth's terminals on the primary circuit at one end at Inverness nine miles away, and at the other end in two directions in a parallel glen about six miles away. The early experiments of 1886, in the valley of the Severn, had placed this question of earth interference beyond the region of doubt, but earth conduction, as a main factor in the results, is still believed in by critics. The function performed by the earth has been thoroughly developed in the Frodsham experiments, and will be discussed subsequently.

One very interesting fact observed at Loch Ness was that there was one particular frequency in the primary circuit that gave a decided maximum effect upon the telephones in the secondary circuit. This proves the pre-

sence of resonance, and is, of itself, a fact sufficient alone to prove the effects as being due to the transformation of electric waves into electric currents.

It is well known that every telephone has one particular note—the natural note of the disc—to which it responds better than to any other, but this resonant effect far exceeded in magnitude any difference due to the natural pitch of the disc. It was not the natural note.

Conversation by telephone, though possible, was not however practical. Still, it is something to have transmitted speech by electricity across an air space of 1½ miles. We had this curious condition, that at some intermediate point the energy of the human voice was found side by side in two different forms—sonorous vibrations in the air, and electric waves in the ether.

There is now no difficulty in communicating with outlying islands if the conditions are favourable. The Northern Commissioners of Lights are anxious to establish electrical communication with the Muckle Flugga Lighthouse, at the extreme north of the Shetland Islands, but the place is so inaccessible that, though the conditions are favourable and signalling without wires is possible and simple, it would be more prudent to adopt the more expensive plan of a submerged cable. I would rather inaugurate the system nearer home, where it could be watched, nursed, and improved. Anyhow, it is something to be able to report that we have now acquired a practical system of signalling across space without the necessity of using wires.

Although this short paper is confined to a description of a simple practical system of communicating across terrestial space, one cannot help speculating as to what may occur through planetary space. Strange, mysterious sounds are heard on all long telephone lines when the earth is used as a return, especially in the calm stillness of night. Earth currents are found in telegraph circuits, and the Aurora Borealis lights up our northern sky when the sun's photosphere is disturbed by spots. The sun's surface must, at such times, be violently disturbed by electrical storms, and if oscillations are set up and radiated through space, in sympathy with those required to affect telephones, it is not a wild dream to say that we may hear on this earth a thunderstorm in the sun.

If any of the planets be populated with beings like ourselves, having the gift of language and the knowledge to adapt the great forces of Nature to their wants, then if they could oscillate immense stores of electrical energy to and fro in telegraphic order, it would be possible for us to hold commune by telephone with the people of Mars.

DISCUSSION.

Mr. PREECE, in answer to a question, stated that the experiments described were performed during the severe weather of last week, and that the wind had no effect upon the results.

Mr. W. GRANVILLE said he was not yet converted to the belief that the effects described were produced by induction, or radiation through space, and not by conduction or leakage; but there was one test which would decide the question. An induced current was only capable of producing a temporary action, whereas a current set up by conduction remained permanent as long as the primary current acted. When, in 1842, Professor Morse bridged a river in America by a somewhat crude method, resembling that shown on the diagram, the apparatus then used was only capable of responding to currents of a certain duration, certainly not to those of such small duration as would be produced by induction. Somewhat later Mr. Preece succeeded in bridging the Solent by a similar method, and he took it the instruments then in vogue were such as would only respond practically to currents of somewhat long duration; and there, again, there was simply the effect of conduction. Some years ago, in conjunction with the late Mr. Willoughby Smith, he had the satisfaction of carrying out a series of experiments at Yarmouth, where they succeeded in communicating from the shore to a small boat about a quarter of a mile off by means of two earth plates carried out to sea, but remaining at a distance of a quarter mile from the boat. Those signals were clearly produced by conduction, for they placed a galvanometer in the circuit, and found that, just as long as the battery current remained on, was it deflected, so that the result could not possibly be produced by induction. There had also been experiments by the Telegraph Construction and Maintenance Company, with a view to communicating with lighthouses; and at Alum Bay they communicated with the Needles through a non-continuous cable, bridging a distance of some 60 yards. In that case, a vibrator and telephone was first tried, but afterwards they substituted for it an ordinary galvanometer; and there they ascertained that the effect was produced by a permanent current, and, therefore, by conduction. With regard to the distance one could signal by means of induction through air, it was found, as the result of a large number of experiments, that if they took two spirals similar to those on the table, the sound fell off very rapidly, as the distance increased, and that with a very strong battery current

it was impossible to bridge a greater distance than about 100 yards. The same result was noticeable in the experiment shown that evening. He therefore must remain unconverted until Mr. Preece was able to inform them of the fact that he had placed a galvanometer in the circuit.

Mr. ALEXANDER SIEMENS said Mr. Preece had the great advantage over most of those present that he had conducted experiments on this most interesting subject, while they had not. He understood him to say that in one of his experiments he used two metallic circuits, so that there could be no doubt as to their being real induction, and not conduction currents which he was dealing with. There was one point to which particular attention should be called, viz., that in one case he had succeeded in calling up the other party. In some of the experiments the difficulty was that you had, by means of a boat, or in some other way, to fix the time at which the experiment was going to be made, in order that the man at the other side might be on the watch, but, in communicating with a lighthouse, it was very important to be able to call to your correspondent when you wanted him. If it was necessary, first, to send an ordinary telegram to say you were going to send a message, you might as well send it all at once. No doubt this method of signalling would be much further developed in the able hands in which it was, and a good deal might be expected from it in future.

Major-General FESTING, F.R.S., said he did not quite gather whether the result of the experiments in the Bristol Channel was to show that the two wires would respond to each other if they were both in the water. He understood that they would, if they were both in the air, or both in the water, but that if one were in the air and the other in the water, they would not.

Lieut.-Col. CUNNINGHAM, R.E., said Mr. Preece seemed to lay great stress on the fact that this inductive effect took place through the ether, and that it would probably take place equally in a vacuum. All the experiments were made across water, but he did not catch whether the wires were on both sides up in the air, or on one side in the air, and on the other in the water. He would also ask if there was any advantage in the long wires being parallel to each other, and further, what was the function of the cable paid out by the steam-launch.

Mr. CHARLES BRIGHT said it was a question at a recent meeting of the Society whether submarine cables or land lines were preferable, and the majority of speakers seemed in favour of land lines. He did not agree in that, but these experiments of Mr. Preece's seemed to point to another method of getting out of the difficulty in cases where a submarine cable was not sufficiently durable, as for instance for communication between lightships and the shore, owing to the continual chafing of the cable on the bottom and against the moorings. In conclusion, he would ask those studying this subject in future to change the title, and he did so in the interest of shareholders and cable contractors, who might think their occupation was gone. It was not really telegraphing without wires, because it appeared that considerable lengths of wire were necessary.

Mr. PREECE, in reply, said he was sorry Mr. Granville should have suggested that he was such a poor electrician as not to have tried the experiment he suggested. One of the first experiments he ever took part in was in the year 1853, when he assisted Mr. Lindsay in endeavouring to communicate across rivers by means of conduction currents. They made a tank to represent a river, and produced very capital results. He had often experimented in that direction, and, as Mr. Granville said, they succeeded in communicating across the Solent, through a broken cable from Hurst Castle, by means of those currents. He did not suppose anybody—unless it were Mr. Granville himself, or Mr. W. Smith—had devoted more attention to conduction currents through water or earth than he had. But there was as much difference between communicating by current through the air and by means of radiation as there was between having a room illuminated by electricity and taking hold of a red-hot poker. All his experiments had been verified by some such system as that adopted on Loch Ness, or by the use of metallic circuits, as was done in London, and also on the Severn and Conway lines. It was quite impossible to conceive that when you had two coils in the air, which were kept wide apart, that there could be any earth action of any sort. Mr. Granville drew attention to the fact that with the two coils he had shown, the sound diminished very rapidly as they were separated. That was so with coils, but if, instead of coils, the wires had been stretched out in straight lines, the distance through which you could communicate increased with the length of the wire; so that if Mr. Granville could communicate with coils 100 yards apart, the probability was that if the same wire had been stretched out straight the distance would have increased to a mile or more. Mr. Siemens had called attention to an important point. The one great difficulty in the earlier experiments was that there was no means of calling attention, but at Loch Ness the sound was so loud at 1½ mile distance that it amounted to a call. The loudness was simply dependent on the materials and means used. With regard to the effects in air and in water on the South Wales coast, and also in the Conway estuary, the sounds were all reproduced in water as well as in air. When the conditions were the same, the effect would be the same. At Lavernock Point, the wires were on 20 feet

poles on the top of a cliff about 70 feet above high-water mark; in this case the electric waves did not pass through the water, they struck the water at a very low angle, which was probably for those waves the angle of total reflection, and the absence of any effect when the cable was sunk, was to him a proof that the waves did not penetrate the water. Had the primary wires been under water there would have been an effect on the submerged cable. He had not experimented in a vacuum, but always either in air or water. How far the air or water took any part in the transmission he could not say, but he had no doubt that the effects would all be traced to the same agency as operated in the case of light and heat, viz., the oscillations of the ether. It was essential to the effect that the wires should be parallel. If the wire on the Flat Holm were perpendicular to the one on Lavernock point he did not think any effect would be produced. The whole theory had been worked out; it was rather complicated and difficult, but he hoped before long to be in a position to write another paper on it. The object of the cable from the launch was first of all to see how far the effects of the earth currents extended, and where the effect of radiation alone appeared. They found that close in shore it made no difference whether the wire was on the surface or submerged, but when they got to a certain distance the difference between the effect of flotation and submersion became evident, and at length submersion caused the effect to disappear entirely. They experimented in that way inland as well as at sea, and inland they were able to plot out the earth currents; they had been plotted, not only there, but for Liverpool, London, and several other places. The object of having the cable suspended was to endeavour to differentiate between the radiations which were evident on the surface, and the earth currents which must have been evident on the surface as well as at the bottom of water. He must admit that the title of the paper was somewhat misleading, but he hoped he had made amends in the concluding particulars in which he had referred to hearing a thunderstorm in the sun, and that he had established some claim to the 300,000 francs which were now lying somewhere in Paris, having been offered as a premium to the man who first showed how to communicate with the inhabitants of Mars.

The CHAIRMAN, in proposing a hearty vote of thanks to Mr. Preece, said the paper had been to him quite a revelation as to matters of which he had hardly ventured to dream as possible. He thought the objection to the title of the paper was rather hypercritical, because ordinary people always understood telegraphing by wire as meaning through the wires going from one station to the other, and these parallel wires not connected would rather be looked upon as the sending and receiving instruments. He hoped, therefore, that the same name would be adhered to in any further development of the subject. He was interested in Mr. Granville's observations, but he, at once, thought of the answer which Mr. Siemens gave as being probably the correct one, and that where there were two complete insulated metallic circuits, the effects could not be due to leakage. He could not help thinking, also, having regard to what was known about induced currents, that the fact that no appreciable current was apparent in the receiving wire when it was perpendicular to the sending wire, would seem to indicate that the effect was produced by radiation or induction. He hoped on some future occasion they would have the privilege of hearing from Mr. Preece of the further development of this subject; one branch of it at least deserved further investigation, and that was the suggestion that the electric waves were reflected from the surface of the water. It was obvious that that would account for the fact that there was no apparent transmission from air to water, or from water to air. While at the same time there was transmission when both wires were either in air or in water. Possibly, also, the theory that the medium of transmission was what was understood as ether, was capable of further investigation.

The vote of thanks was carried unanimously, and the meeting adjourned.

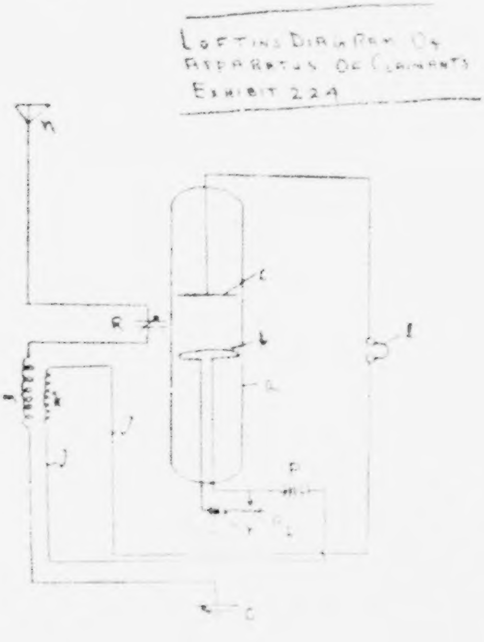
Correspondence.

MODERN DEVELOPMENT OF ILLUSTRATED JOURNALISM.

MR. JOHN LEIGHTON, F.S.A., writes:—Mr. Townsend seems to have ignored the early stages of process, where the artist became his own engraver, and laid his own lines before photography and chemistry engraved them for him. I well remember that it was early in the forties that one of the Fourdriniers—a son of the inventor of the paper-making machine—had a method that he called gypsograph, it was a drawing with a point made through a surface of plaster down to a plate, and into which lines a stereotype cast entered, producing a relief block, that when bold was effective. Then there was the *Procédé Comte* by which many handsome works were done in Paris, and one has only to instance *L'Art pour tous* and the very large natural history subjects by Karl Bodmer, of Barbezon, that were first published in "*L'Illustration*" to see how the artist's touch was maintained, as in an etching. Then, again, there was "*La Vie Moderne*," an imitation of "*The Graphic*," only it was all process. A system that I employed in my "Suggestions in Designs," consisting of 1,100 designs, done in Paris by the Frères Comte and published about 1878, and printed on a tint, in a belief that it would defy photographic reproduction,

DEFENDANT'S EXHIBIT V 6

Sketch made by Loftin at R. 2070



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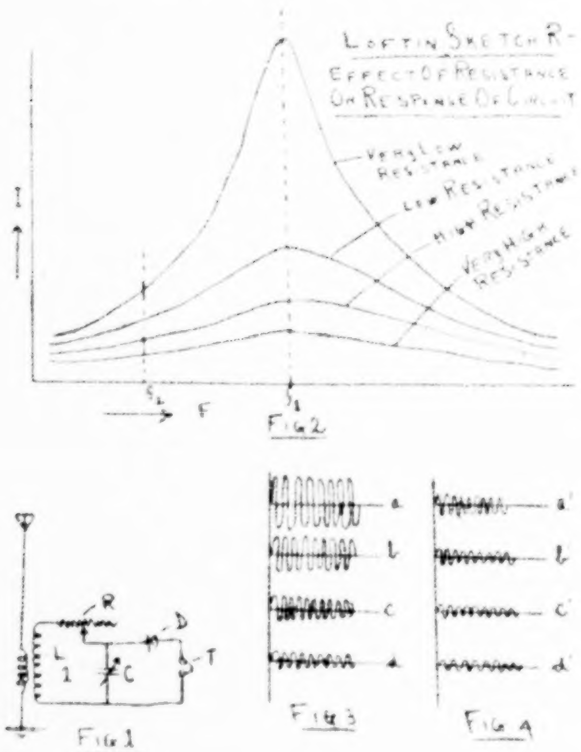
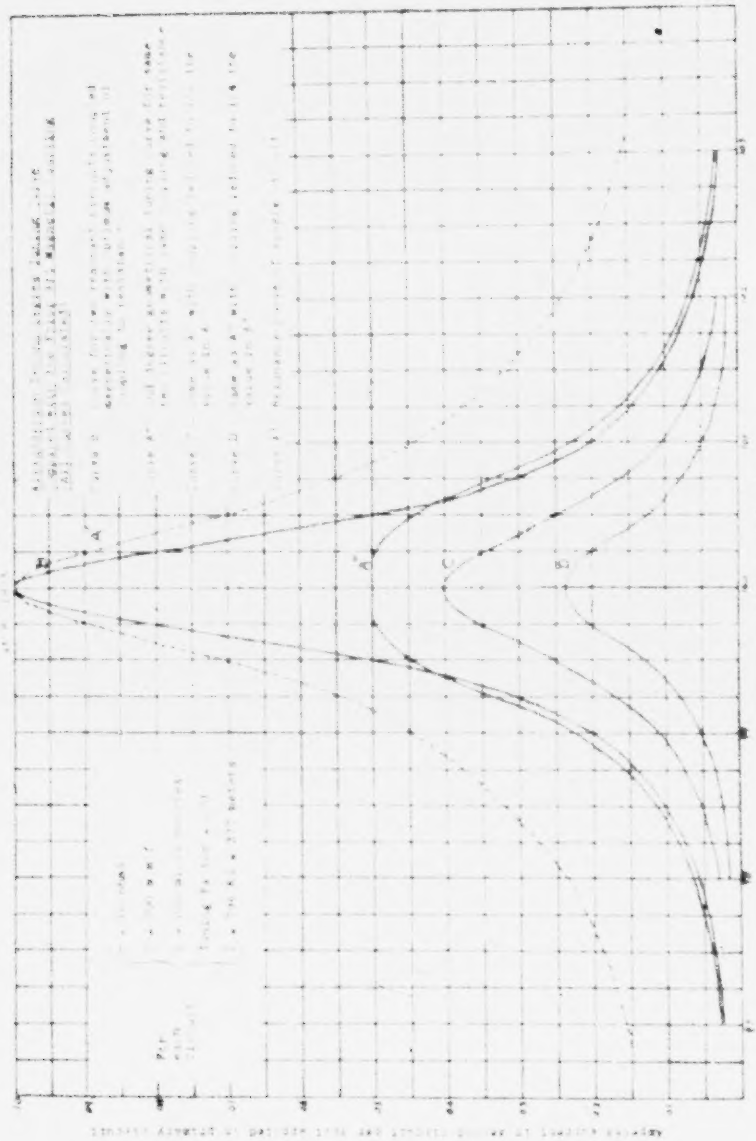
DEFENDANT'S EXHIBIT W 6

Sketch made by Loftin at R. 2097



DEFENDANT'S EXHIBIT Y-6

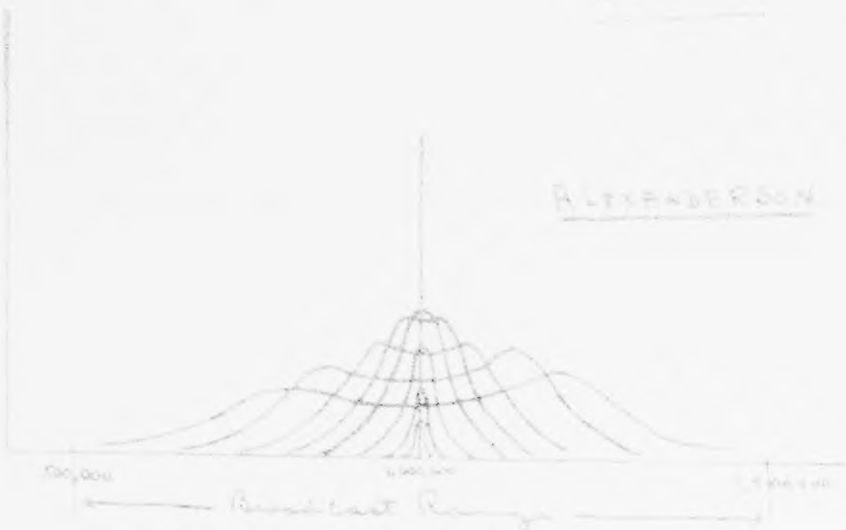
Shown witness Waterman at R. 1978



DEFENDANT'S EXHIBIT Z 6

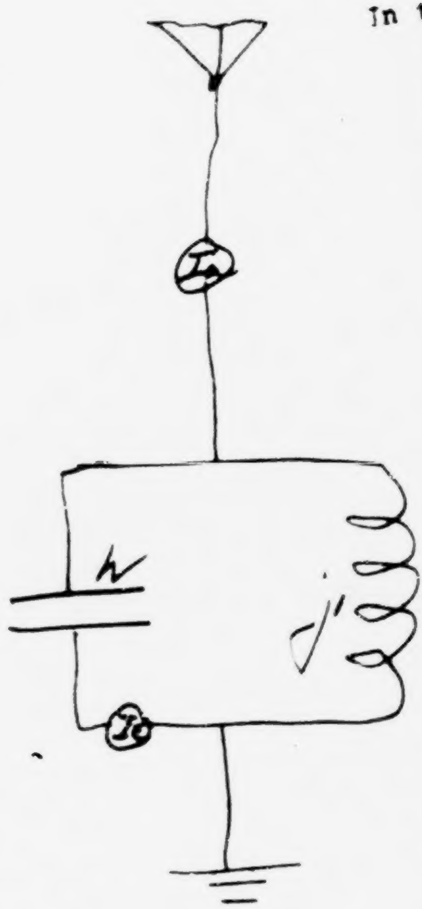
Shown witness Waterman at R. [illegible]

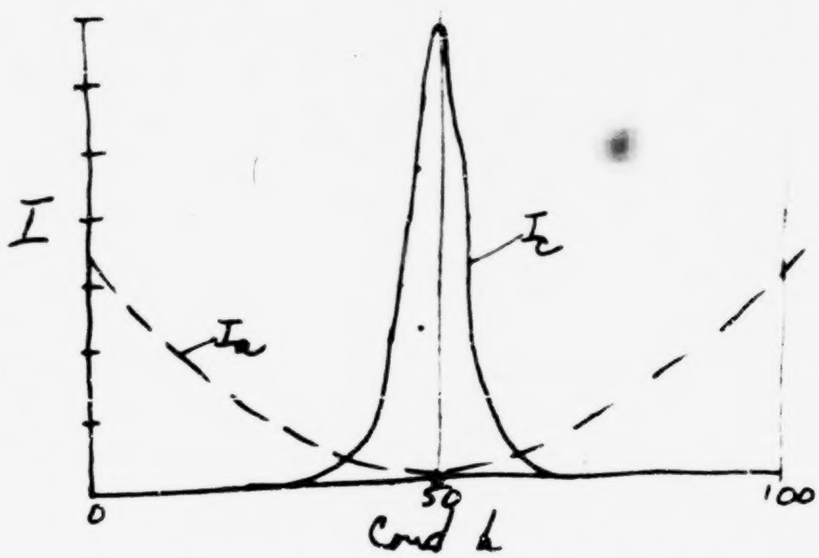
U. S. District Court



Defendant's Ex. JJ

Marconi v. U.S.
In the United States Court of Claims
No. 33,642
EXHIBIT
DEFENDANT NO. JJ
DATE 6/19/39
Edward W. Cooper, C. S. R.
LAW REPORTER





3717-3731

Defendant's Exhibit MM

EXHIBIT
Defendant NO. MM
DATE 6/30/39
Edward W. Cooper, C.S.R.
LAW REPORTER

Fig 1 Fessenden

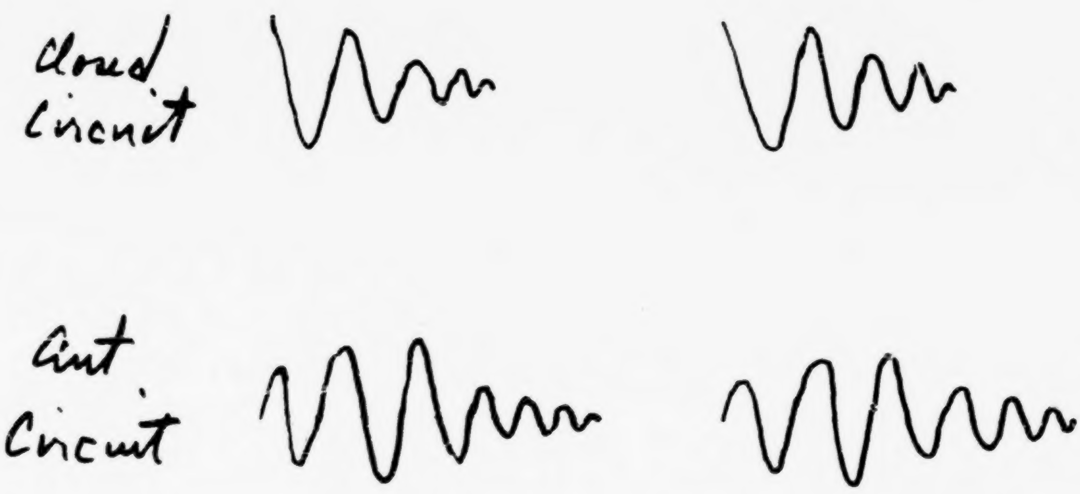


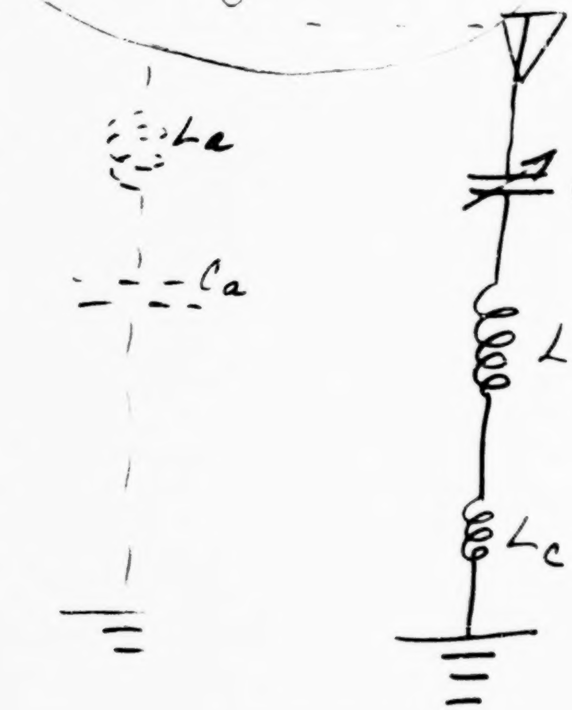
Fig 2 Marconi

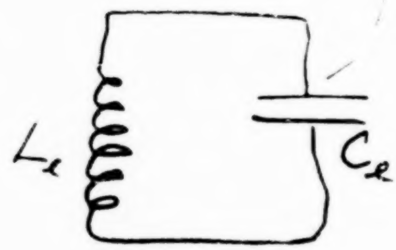
Defendant's Exhibit PP

Deft Exh PP JH 7/1/34

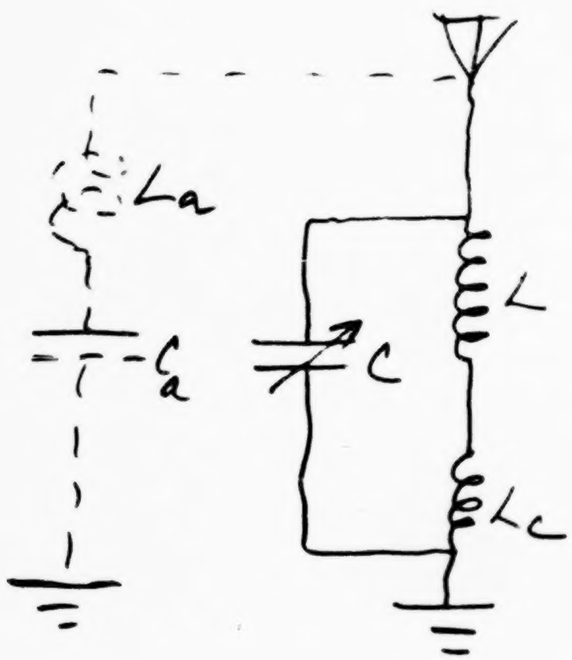
$$L_e = L + L_a + L_c$$

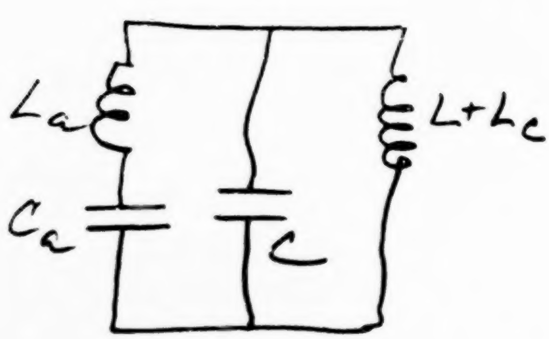
$$\frac{1}{C_e} = \frac{1}{C_a} + \frac{1}{C}$$





Equiv. Simple Circuit





Equiv. Simple Circuit.

DEFENDANT'S EXHIBIT BBB

BBB

MARCONI ANTENNA CIRCUIT "TUNES"

MARCONI TRANSMITTER		MARCONI RECEIVER			
Tune No.	Approx. W/L meters	Overall W/L	W/L ~~1f~~ ~~j_1 omitted~~ of series circuit f'g'hE alone	Substantially constant, non-varied, second resonance wave-length of Marconi receiver (that of wheel circuit hj_1 with antenna and load coil as dead-end)	Resonance frequency of Wheel circuit hj_1 alone
1	205	205.7	——	——	——
2	302	302.1	——	——	——
3		142.3 (g'=0)	142.3	1628	1640
		166.4 (g'= 10)	166.4	1631	2640
	199	199.2 (g' = 21)	199.3	1634	1640
4	364	364.1 (g' = 100)	364.6	1641	1640
5	-	This tune is series only, h omitted as in tune 1			
6	-	This tune is series only, h omitted as in tune 1			

Marconi Wireless Telegraph
Deft's 33 ex No. [illegible]
BBB

1116

(Vols. 3735-3743) Deft's Ex. FFF

Sept. 2, 1924. **1,507,016**

L. DE FOREST

RADIOSIGNALING SYSTEM

Filed Sept. 23, 1915 2 Sheets-Sheet 1

Fig 1

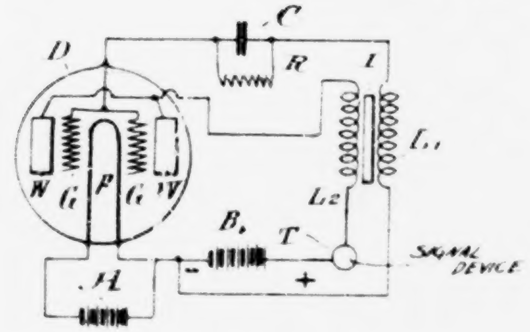
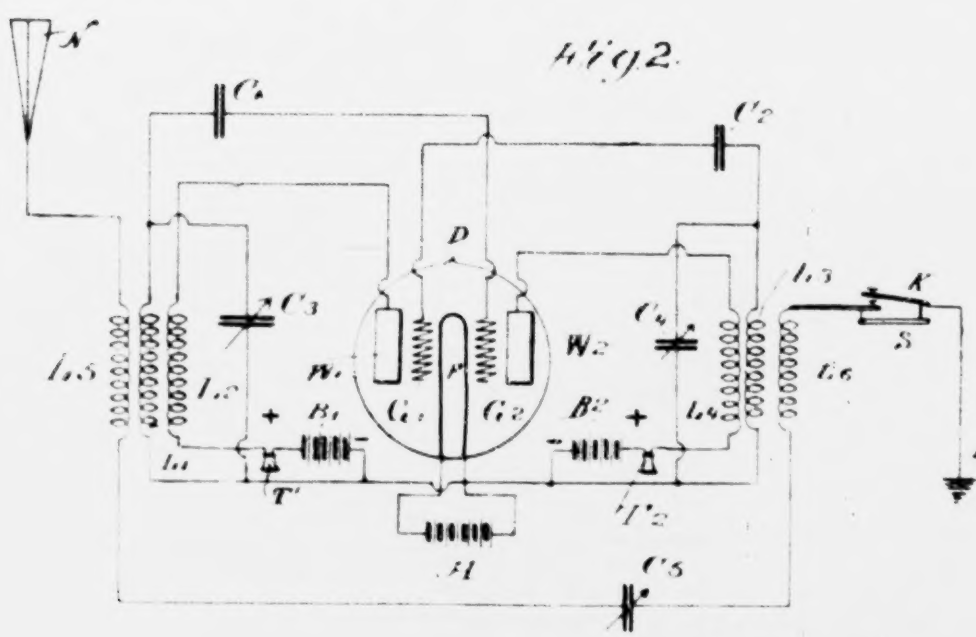


Fig 2.



Inventor:
Lee de Forest
By his Attorney
Samuel E Darby

3735-3736

1117

Sept. 2, 1924. 1,507,016

L. DE FOREST

RADIOSIGNALING SYSTEM

Filed Sept. 23, 1915 2 Sheets-Sheet 2

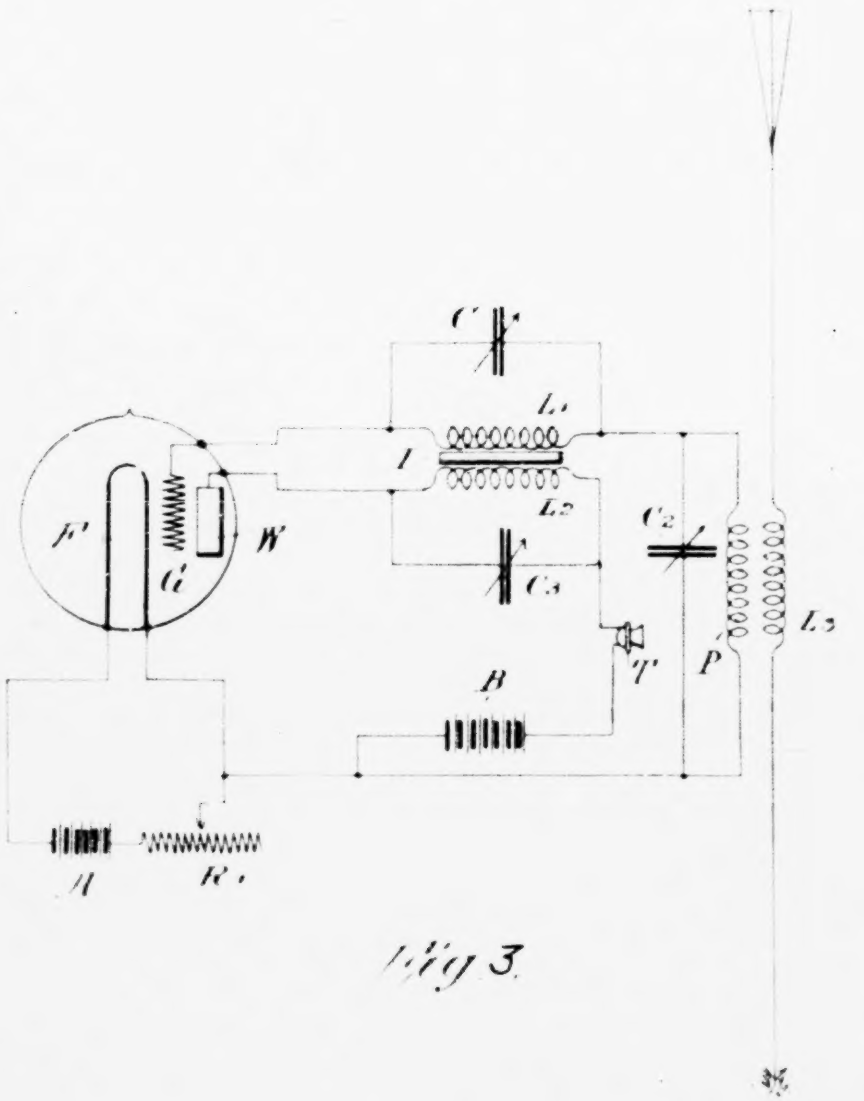


Fig 3.

Lee de Forest Inventor
By his Attorney
Samuel E. Darby

Patented Sept. 2, 1924. **1,507,016**

UNITED STATES PATENT OFFICE.

LEE DE FOREST, OF NEW YORK, N. Y., ASSIGNOR TO DE FOREST RADIO TELEPHONE AND TELEGRAPH COMPANY, OF NEW YORK, N. Y., A CORPORATION OF DELAWARE.

RADIOSIGNALING SYSTEM.

Application filed September 23, 1915. Serial No. 52,176.

To all whom it may concern:

Be it known that I, LEE DE FOREST, a citizen of the United States, residing in the city of New York, county of Bronx and State of New York, have made a certain new and useful Invention in Radiosignaling Systems, of which the following is a specification.

This invention relates to radio signaling systems.

The object of the invention is to provide a radio signaling system which is simple and efficient in operation.

Further objects of the invention will appear more fully hereinafter.

The invention consists substantially in the construction, combination, location and relative circuit arrangements all as will be more fully hereinafter set forth, as shown in the accompanying drawing and finally pointed out in the appended claims.

Referring to the drawing, Figs. 1, 2, 3, all show various circuit arrangements embodying my invention.

In accordance with my present invention, I propose to employ an evacuated vessel with hot and cold electrodes therein, known as the audion, together with suitable circuit connections to cause the audion to operate as a generator of undamped oscillations, and to so arrange the circuit connections to cause the audion to operate as a generator of undamped oscillations, and to so arrange the circuit connections referred to so as to allow such a generator to also be employed as a detector. The underlying principle of my present invention as will be more fully described, is the association, preferably by inductive coupling means, of the circuits of the cold electrodes of the audion.

In Fig. 1 I have shown a simple circuit arrangement for accomplishing the objects of my invention wherein D is the exhausted vessel, F the hot or filament electrode, and A is the battery for heating the same in the usual and well known manner and controlled by the resistance R_1 as shown in Fig. 4, if desired. G designates the grid or "input" electrodes and W the wing or "output" electrodes. Preferably, and as shown, though I do not desire to be limited in this respect, the wing and grid electrodes are arranged in pairs, both grids and both wings being connected in parallel. The input electrodes G are connected to one side of the filament F by a circuit including therein one coil of a transformer L_1. The output electrodes W are likewise connected to the filament F by a circuit including the coil L_2 of the transformer, and the usual source of voltage such as battery B or other direct current source with its positive terminal connected to the cold electrodes W through the telephone or signal indicating device T, as shown.

In series with the grid or input electrodes G and in the circuit thereof I propose to place a stopping condenser C, and to shunt around this condenser a high and preferably non-inductive resistance R, of from 25,000 to 100,000 ohms.

The transformer whose coils are L_1 L_2 may be a "telephone transformer" as shown, with the coils having several thousands turns each surrounding an iron core I, in which case the system will oscillate at "audio" or low frequencies, or the windings may contain only a few hundreds of turns each, of several milli-henries inductance, and the coils more or less spatially separated or "loosely coupled" in which case the system will oscillate at high or "radio" frequencies.

In the first case, that is, when the system is oscillating in "audio" frequencies the system becomes a "siren" and will generate powerful telephonic currents having a clear musical note heard in the telephone receiver T. The pitch of this note can be varied by altering the inductance of either of the coils L_1 L_2 in any well known manner, or by altering their coupling as by withdrawing from the transformer the iron core I, or by varying the distributed capacity of the winding or the spatial relation of the windings, or the capacity of the condenser C, the value of the resistance R, or the potential of the battery B, or the brightness of the filament F in any manner well known in the art.

When such an oscillating system as shown in Fig. 1, is employed for generating radio frequencies, the capacity of the ordinary telephone wires leading to the telephone receiver or signaling device T is usually sufficient to form a by-path around the high impedance and high resistance of this device. The impedance of source B to the

radio frequency oscillations, I have found to be insufficient to materially dampen the same. My invention as defined in the claims is not to be limited in this respect however, for other expedients will readily suggest themselves to those skilled in the art.

If the system described is to be employed as a generator of high frequency oscillations for transmission purposes the signal device T may be a transmitter if desired. An alternative arrangement is shown in Fig. 2 wherein a key indicated at K is inserted in the antenna earth system. As it is obvious that my invention applies to either transmitting or receiving systems, I wish it to be understood that by the term "signal device," as used throughout the specification, I mean broadly either a transmitter or a receiver of signals.

When an audion with its cold electrodes associated or inter-linked as shown, is used as a receiving system its ordinary sensitiveness as a detector is many times increased by virtue of the "kick back" or progressively amplifying effect of the received signal impulses.

In Fig. 2 I have illustrated a "compound audion" containing two insulated grid members G_1 and G_2, and two insulated wing members W_1 and W_2, each of the four electrodes being connected to the filament F by a circuit containing inductances L_1, L_3, L_2, and L_4, respectively. The coils L_1, L_2, may be inductively associated as shown, and likewise inductances L_3, L_4, may be inductively associated, so as to allow reaction of the one upon the other in each pair.

As shown, I prefer to associate the grid nearest one wing with the current of the wing lying furthest away, usually on the opposite side of the filament, as thereby I find that the reaction of the circuits upon each other is the most violent. Each wing W_1 W_2, has, preferably, its own source of electro-motive force as indicated at B_1, B_2, respectively, although I am not to be limited in this respect as it is obvious that a common source may be employed. In the circuit of the sources B_1 and B_2, I employ telephone receivers T_1, T_2, preferably, one receiver for each ear of the operator. I employ the usual stopping condensers C_1 and C_2 in the circuits of the grids G_2 and G_1, respectively, and the variable capacities C_3 and C_4, shunted around the coils L_1, L_3, to render the grid circuits oscillatory. The coils L_1, L_2, and L_3, L_4 of the two oscillating circuits are associated inductively or otherwise to the same antenna-earth system comprising the usual elements N, L_5, C_5, L_6, and E, as shown, whether the arrangement be used for receiving or transmitting signals.

When using the arrangement shown in Fig. 2, as a generator of alternating currents the sources of the wing currents, B_1 and B_2, respectively, should be of high voltage, as for example, direct current generators of from 600 to 1200 volts.

In the antenna-earth system, I show a transmitting key K connected directly therein. I also employ a hand operated switch S shunted around the same to cut the key K out when the system is used as a receiving system. The periodicities of the oscillating circuits L_1, C_3 and L_3, C_4, should be made the same, or nearly the same by properly adjusting their respective capacities or inductances. If the natural rates of oscillation of these two circuits are not quite the same, beats or interferences are set up in the antenna, resulting in a harmonic variation of amplitudes of the radiated wave train which may be of practical value when signaling to receiving stations where the receiver can give audible responses only to interrupted or intermittent trains of waves.

It will be noted that in accordance with my invention, the connection of the terminals of the wing and grid coils is important. I have found that the oscillations set up are much more intense when one end of one of these coils is connected to the grid or plate as the case may be, than when the opposite end of that coil is thus connected. In other words, by reversing coil L_2 relative to coil L_1, the oscillations set up may be found to be much more intense than before such reversal of connections. The principle here involved is that the phase of the two pulsating currents in the coils L_1 and L_2, shall be so displaced relative to each other that a positive charge or surge upon the wing electrodes shall be next followed by a negative charge or surge upon the grid, the effect of this being that thereby an increase of current through the coil L_2 to the wing results in a succeeding increase in the resistance of the gas path between the wing and the filament electrodes, and conversely, a diminution in the current from the wing to the filament electrodes results in a succeeding decrease in the resistance of the path. It is by these means that one circuit is enabled to react upon the other so that successively increasing pulsations are set up in the two associated circuits until the losses by resistance, leakage and load, are equal to the increment of energy supplied from the battery or source B B_1, B_2 whereupon a stable condition of oscillation or pulsation is attained.

In Fig. 3 I have shown a modified arrangement wherein the wing and grid circuits are inductively associated as in Fig. 1, through coils L_1 and L_2 around which are shunted capacities C and C_4, respectively. In this arrangement I prefer to associate the grid circuit with the antenna earth circuit through inductance L_4 of the antenna

system. In this instance I shunt a capacity C_2 around the inductance P as shown. The core I is also used in coupling between the oscillating circuits of the cold electrodes, and the reaction effect is secured between these circuits as hereinbefore described.

It will be understood that many other circuit arrangements will readily occur to those skilled in the art without departing from the broad scope of my invention as defined in the claims. Therefore, having set forth the objects and nature of my invention, and having shown and described various embodiments thereof, what I claim as new and useful and of my own invention and desire to secure by Letters Patent, is,—

1. In a radio signaling system, an evacuated vessel including hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, separate circuits connecting each of the cold electrodes to the hot electrode, said circuits being inductively associated.

2. In a radio signaling system, an evacuated vessel containing hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, separate oscillating circuits connecting each of said cold electrodes to said hot electrode, said circuits being inductively associated.

3. In a radio signaling system, an evacuated vessel including hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, separate circuits connecting each of the cold electrodes to the hot electrode, said circuits being inductively associated, and an antenna system associated with said circuits.

4. In a radio signaling system, an audion including hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, separate circuits connecting each of said cold electrodes t said hot electrode, and means to set up successively increasing pulsations in said circuits, and an antenna system inductively associated with said circuits.

5. In a radio signaling system, an audion including hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, separate oscillating circuits connecting each of the cold electrodes to said hot electrode, said circuits being inductively coupled and an antenna system inductively associated with said coupling.

6. In a radio signaling system, an evacuated vessel containing hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, separate circuits connecting each of said cold electrodes with said hot electrode, said circuits being inductively associated, a source of electromotive force and a signaling device being included in one of said circuits.

7. In a radio signaling system, an evacuated vessel containing hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, circuits connecting each of said cold electrodes with said hot electrode, said circuits being inductively coupled, a source of electromotive force and a signaling device being included in one of said circuits and an antenna system inductively associated with said coupling.

8. In a radio signaling system, an evacuated vessel containing hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, circuits connecting each of said cold electrodes with said hot electrode, said circuits being associated, a source of electromotive force and a signal indicating device being included in one only of said circuits and an antenna system associated with said circuits, and means for operating said radio signaling system as a transmitting station.

9. In a radio signaling system, an evacuated vessel containing hot and cold electrodes therein, circuits connecting each of said cold electrodes with said hot electrode, said circuits being inductively associated, a source of electromotive force and a signal indicating device being included in one of said circuits and an antenna system associated with said circuits, and means for operating said signaling system as a receiving station.

10. In a radio signaling system, an audion including hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, separate circuits connecting each of said cold electrodes to said hot electrode, said circuits being inductively associated with each other.

11. In a radio signaling system, an evacuated vessel containing a hot electrode and a plurality of grid electrodes and a plurality of wing electrodes, circuits connecting each of said grid electrodes and said wing electrodes with said hot electrode, the circuits of the grid electrodes being inductively associated with the circuits of the wing electrodes.

12. In a radio signaling system, an evacuated vessel containing a hot electrode and a plurality of grid electrodes and a plurality of wing electrodes, circuits connecting each of said grid electrodes and said wing electrodes with said hot electrode, the circuits of the grid electrodes being associated with the circuits of the wing electrodes respec-

tively, and a signal indicating device included in each of the circuits of said wing electrodes.

13. In a radio signaling system, an evacuated vessel containing a plurality of wing electrodes and a plurality of grid electrodes, a filament electrode interposed between said grid electrodes and between said wing electrodes, circuits connecting each of said wing and grid electrodes with said filament electrode, the circuits of said grid electrodes being inductively associated with the circuits of said wing electrodes respectively.

14. In a radio signaling system, an evacuated vessel, containing a plurality of wing electrodes and a plurality of grid electrodes, a filament electrode interposed between said grid electrodes and between said wing electrodes, circuits connecting each of said wing and grid electrodes with said filament electrode, the circuit of each of said grid electrodes being inductively associated with the circuit of said wing electrode on the opposite side of said filament electrode.

15. In a radio signaling system, an evacuated vessel containing a plurality of wing electrodes, and a plurality of grid electrodes, a filament electrode interposed between said grid electrodes and between said wing electrodes, circuits connecting each of said wing and grid electrodes with said filament electrode, the circuits of said grid electrodes being inductively coupled with the circuits of said wing electrodes respectively.

16. In a radio signaling system, an evacuated vessel containing a plurality of wing electrodes and a plurality of grid electrodes, a filament electrode interposed between said grid electrodes and between said wing electrodes, circuits connecting each of said wing and grid electrodes with said filament electrode, the circuits of said grid electrodes being inductively coupled with the circuits of said wing electrodes respectively, and an antenna system inductively associated with said coupling.

17. In a radio signaling system, an evacuated vessel containing a plurality of wing electrodes, and a plurality of grid electrodes, a filament electrode interposed between said grid electrodes and between said wing electrodes, circuits connecting each of said wing and grid electrodes with said filament electrode, the circuits of said grid electrodes being inductively coupled with the circuits of said wing electrodes respectively, the circuit of each of said grid electrodes being inductively coupled with the circuit of said wing electrode on the opposite side of said filament.

18. In a radio signaling system, an evacuated vessel containing a plurality of wing electrodes, and a plurality of grid electrodes, a filament electrode interposed between said grid electrodes and between said wing electrodes, circuits connecting each of said wing and grid electrodes with said filament electrode, the circuits of said grid electrodes being inductively coupled with the circuits of said wing electrodes respectively, the circuit of each of said grid electrodes being inductively coupled with the circuit of said wing electrode on the opposite side of said filament, and an antenna system inductively associated with each said coupling.

19. In a system for generating oscillations, a work circuit, and means for generating and transmitting the generated oscillations comprising an oscillatory circuit having two electrodes in an exhausted receptacle, and a second circuit inductively coupled thereto having a conducting body interposed between said electrodes.

20. In a system for generating oscillations, a work circuit, and means for generating and transmitting the generated oscillations comprising an oscillatory circuit having two electrodes, a second circuit inductively coupled thereto and having a conducting body interposed between said electrodes.

21. In a system for generating oscillations, a work circuit, and means for generating and transmitting the generated oscillations comprising an oscillatory circuit having two electrodes, a second circuit inductively coupled thereto and having a conducting body interposed between said electrodes and means for varying the frequency of the produced oscillations.

22. In a system for generating oscillations, a work circuit, and means for generating and transmitting the generated oscillations comprising an oscillatory circuit having two electrodes means for producing a flow of current between said electrodes and a second circuit inductively coupled with the first circuit and having a conducting body interposed between said electrodes.

23. In a system for generating oscillations, a work circuit, and means for generating and transmitting the generated oscillations comprising an oscillatory circuit having two electrodes means for producing a flow of current between said electrodes and a second oscillatory circuit inductively coupled with the first oscillatory circuit and having a conducting body interposed between said electrodes.

24. The method of generating alternating currents which consists in causing current to flow in one of two inductively coupled circuits, and varying the flow of current in the first circuit by impressing the potential induced in the second circuit upon a conducting body interposed between two electrodes in the first circuit.

25. Means for producing sustained electrical oscillations comprising an oscillatory circuit having two electrodes in an exhaust-

ed receptacle and a second circuit coupled thereto having a conducting body interposed between said electrodes.

26. Means for producing sustained electrical oscillations comprising an oscillatory circuit having two electrodes, a second circuit coupled thereto having a conducting body interposed between said electrodes, and means for varying the frequency of the produced oscillations.

27. Means for producing sustained electrical oscillations comprising an oscillatory circuit having two electrodes. means for producing a flow of current between said electrodes, and a second circuit coupled with the first having a conducting body interposed between said electrodes.

28. The method of producing electrical alternating currents which consists in causing current to flow in one of two coupled circuits and varying the flow of current in the first circuit by impressing the potential induced in the second circuit upon a conducting body interposed between two electrodes in the first circuit.

29. In a system for generating electrical oscillations, a work circuit, and means for generating and transmitting the generated oscillations to said work circuit comprising an evacuated vessel having a hot electrode, a cold plate electrode and a cold grid electrode, said cold electrodes being electrically associated with each other, and a source of current for the hot electrode.

30. The method of producing high frequency alternating currents, which consists in causing current to flow in one of two associated circuits and varying the flow of current in the first circuit by impressing a charge induced in the second circuit upon an element in the space between the electrodes respectively included in said second circuit.

31. Means for generating high frequency oscillations, including an evacuated vessel having separated wing, grid and filament electrodes therein, circuits for said electrodes, and a source of current supply having its terminals respectively connected to two of said electrodes and operating to generate oscillations in one of said electrode circuits.

32. The combination with a work circuit and means for generating and transmitting the generated alternating currents to said work circuit, comprising an evacuated vessel having a hot and a plurality of cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, means to supply current to said electrodes, and circuit connections between said electrodes.

33. The combination with a work circuit and means for generating and transmitting the generated alternating current to said work circuit, comprising an evacuated vessel having a hot and a plurality of cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, a circuit connection between the cold electrodes, and means for impressing an electromotive force in the space between the cold and hot electrodes, and means to supply current to the hot electrode.

34. The combination with a work circuit and means for generating and transmitting the generated alternating currents to said work circuit, comprising an evacuated vessel having a hot and a plurality of cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, a circuit connection between the cold electrodes, a circuit connection between one of the cold electrodes and one side of the hot electrode, a source of current included in said last-mentioned circuit connection, and means for supplying current to the hot electrode.

35. A work circuit and means for generating and transmitting the generated oscillations to said work circuit, comprising an audion and its associated circuits.

36. The combination with a work circuit and means for generating and transmitting the generated oscillations to said work circuit, comprising an evacuated vessel having filament, grid and plate electrodes therein, means to supply current to said electrodes, and circuit connections between said electrodes.

37. In a system for generating electrical oscillations, an evacuated vessel having a hot electrode, a cold plate electrode and a controlling electrode, circuits connected to said cold plate electrode and said controlling electrode, respectively, and coupled with each other, and a source of current for the hot electrode.

38. The combination with a translating device, of means for generating and transmitting to said device the generated oscillations, comprising an evacuated vessel having filament, grid and plate electrodes, means to supply current to said electrodes, and circuit connections between said electrodes.

39. Means for producing sustained electrical oscillations, comprising an oscillatory circuit having two electrodes, one of said electrodes comprising an incandescent filament, a second circuit coupled to said oscillatory circuit and having a controlling grid electrode for regulating the discharge between said two electrodes.

40. Means for producing electrical oscillations comprising an oscillatory circuit having two electrodes, one of said electrodes comprising an incandescent filament, a second circuit coupled thereto having a con-

trolling grid electrode associated with said electrodes, and means for varying the frequency of the produced oscillations.

41. The method of producing electrical oscillations with an incandescent filament thermionic discharge device having two coupled circuits each connected to the incandescent filament thereof, which consists in causing current to flow in one of the said two coupled circuits and varying the flow of current in said first circuit by impressing the potential induced in the second circuit upon a controlling grid electrode regulating the current flow in the first circuit.

In testimony whereof I have hereunto set my hand in the presence of a subscribing witness, on this 18th day of September, A. D., 1915.

LEE DE FOREST.

Witness:

S. E. DARBY.

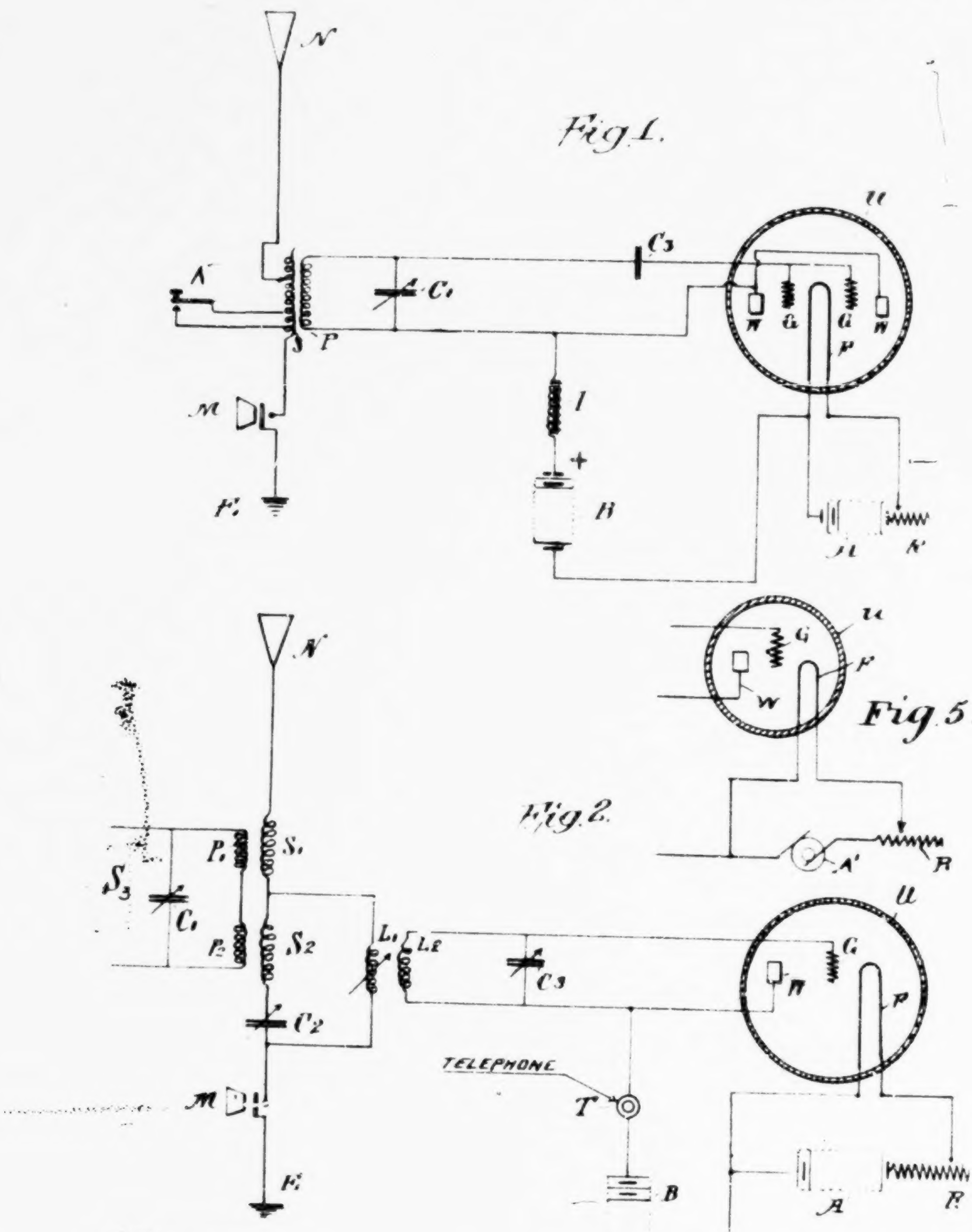
DEFENDANT'S EXHIBIT UUU 4121

Sept. 2, 1924. 1,507,017

L. DE FOREST

WIRELESS TELEGRAPH AND TELEPHONE SYSTEM

Filed March 20, 1914 2 Sheets-Sheet 1



Witnesses:
S. E. Darby, Jr.
W. R. Darby.

Inventor
Lee de Forest
By his Attorney
Samuel E. Darby

3744-3745

4125

Sept. 2, 1924. 1,507,017

L. DE FOREST

WIRELESS TELEGRAPH AND TELEPHONE SYSTEM

Filed March 20, 1914 2 Sheets-Sheet 2

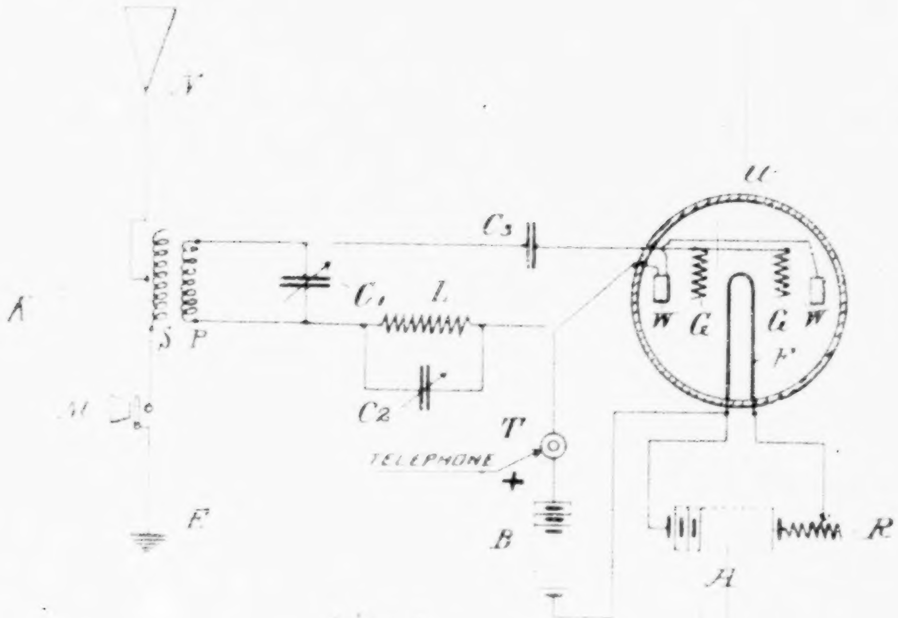


Fig 3

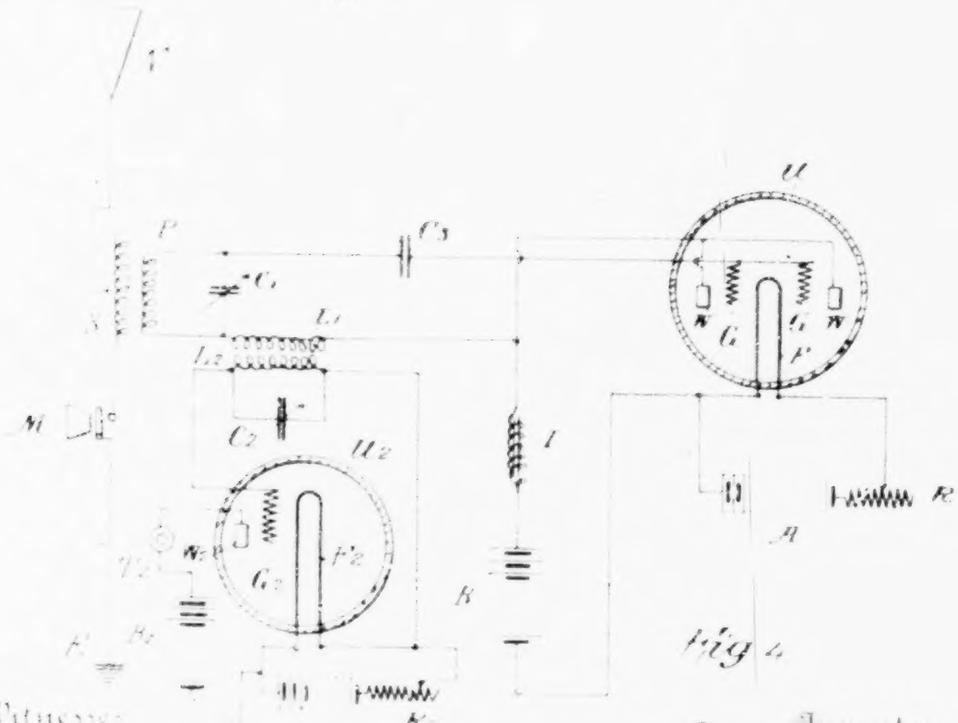


Fig 4

Witnesses

Inventor

Lee de Forest

by his Attorney

3746

1127

Patented Sept. 2, 1924. 1,507,017

UNITED STATES PATENT OFFICE.

LEE DE FOREST, OF NEW YORK, N. Y., ASSIGNOR TO RADIO TELEPHONE & TELEGRAPH COMPANY, A CORPORATION OF DELAWARE.

WIRELESS TELEGRAPH AND TELEPHONE SYSTEM.

Application filed March 20, 1914. Serial No. 825,954.

To all whom it may concern:

Be it known that I, LEE DE FOREST, a citizen of the United States, residing at New York, in the county and State of New York, have made a certain new and useful Invention in Wireless Telegraph and Telephone Systems, of which the following is a specification.

This invention relates to wireless telegraph and telephone systems.

The object of the invention is to provide a wireless telegraph and telephone system which is simple and efficient and wherein provision is made for duplex operation whether for telegraphing or telephoning.

A further object is to provide a more perfect generator of high frequency oscillations of uniform amplitude.

A further object is to provide a system of the nature referred to employing an oscillation generator which combines detector functions with its functions as a generator and to utilize the combined functions thereof for duplex operation.

Other objects will appear more fully hereinafter.

The invention consists substantially in the construction, combination, location and relative arrangements of parts all as will be more fully hereinafter set forth, as shown in the accompanying drawings, and finally pointed out in the appended claims.

Referring to the drawings,—

Fig. 1 is a circuit diagram showing one arrangement embodying my invention wherein the device serves as a generator of continuous oscillations.

Fig. 2 is a circuit diagram showing an arrangement whereby the receiver is not affected by the energy being radiated from the home antenna.

Fig. 3 is a circuit diagram showing an arrangement wherein the same device serves as an oscillation generator and a detector.

Fig. 4 is a similar view showing a modified arrangement wherein a detector separate from the oscillation generator is employed.

Fig. 5 is a similar view of a modified form of detector employed in accordance with my invention.

In the drawing N designates the antenna for transmitting and receiving. Adjustably connected in the antenna circuit is an inductance S. The antenna circuit is connected to earth or other capacity E, and, where the apparatus is to be used for telephonic communication the antenna includes a microphone transmitter M. Where the apparatus is to be used for telegraphing a Morse telegraph key K is bridged across a portion of the inductance S. The inductance S is in the form of a coil with which is inductively associated, preferably in loose coupled relation, an inductance coil P, one terminal of which is connected to auxiliary or cold grid electrodes G, G, arranged within an evacuated bulb or vessel U. The other terminal of coil P is connected to the cold plates or electrodes W also arranged within the bulb U. Connected across the terminals of coil P is a variable capacity C_1. In series with the coil P and electrodes G, I place a blocking condenser C_3, and if desired, (see Fig. 3), in series with the coil P and electrode plates W, I place an inductance coil L, across the terminals of which is connected a variable capacity C_2. Contained in the bulb U is a hot electrode F, which is, in the form shown, a filament or glower, to which current is supplied from any convenient source indicated at A, the current supply being regulated by a rheostat R.

As above indicated the current source A may be of any desired form, such for instance as a battery, direct current generator, or an alternating current generator. Where an alternating current generator is employed, as indicated in Fig. 5, the frequency, for wireless telephone operation, should be above that of the essential frequencies of voice sounds, say fifteen hundred cycles per second, or higher. For wireless telegraph work the frequency of the generator may be very much lower, for example, five hundred per second.

A telephone receiver T is connected on one side in series with the plate electrodes W, and on the other side in series with the filament F. In circuit with the telephone T, is a source of current supply indicated at B, as a battery, the purpose of which is to impress an electro-motive force between the cold plate electrodes W, and the filament F.

By reason of the arrangement above de-

scribed the device U with its associated electrodes and filaments and their associated circuits and connections, becomes a generator of alternating or pulsating electric currents or continuous oscillations of high frequency in the circuit of coil P, the frequency of which depends upon the spatial relation of the electrode members contained therein, the value of the electro-motive-force impressed across the electrodes, and the amount of inductance and capacity included in or associated with the circuit of said coil. In the arrangement shown in Fig. 3 the frequency of such oscillations may be varied by varying the capacity of condensers C_1 or C_2.

By reason of the relation of coils P and S, the oscillations in the circuit of coil P are impressed upon the antenna-earth system and with a natural period of oscillation in the antenna-earth system the same as that of the oscillations in the circuit of primary coil P.

The amplitude of the oscillations induced in the antenna-earth system as above described may be varied by and in accordance with sound waves falling upon the microphone transmitter M in the usual manner. Similarly, a telegraph key associated in the antenna-earth system may serve to control the emission of wave trains in accordance with the telegraphic code, or, if desired, and as shown, if the key K is associated with the antenna-earth system in such a manner as to short circuit a portion of the inductance S, the wave length of the emitted wave trains may be altered in a manner well understood in the art.

It will be seen that, in the arrangement shown in Fig. 3, the device U, with its associated electrodes and filament and circuit arrangement therefore combines within itself the functions of a source of continuous oscillations and also those of a detector, like the audion detector, and its detector functions are in no way impaired by its simultaneous operation as an oscillation generator. Incoming electro-magnetic signals influence the circuits of the electrodes G and W, and produce an alteration in the conducting qualities of the medium between the plate and grid electrodes, and consequently any received signals when attuned to the proper wave length will be heard in the receiver T, during the pauses between the signals being made by the operation of the key K, or between the words spoken into the microphone transmitter M. By this simple arrangement, as described, I am enabled to secure duplex operation whether for telegraphing or telephoning, employing the same apparatus for transmitting and receiving.

It is obvious that provision may be made to protect the telephone receiver T in case large amounts of current are to pass across the space in the bulb U. Any suitable means may be employed for this purpose, as, for instance the usual high resistance telephone receiver may be employed, which, if desired, may be coupled to the circuit containing the battery B, electrodes W and filament F, in any suitable or well known manner.

In Fig. 1 I have shown an arrangement wherein a detector device independent of and separate from the oscillation generator is employed. In this arrangement I employ for the detector an evacuated bulb U_2 with a filament F_2, and a grid G_2 and a plate W_2 similar to corresponding parts above described with reference to bulb U, the filament circuit being supplied with current from a current source A_2, controlled by a rheostat R_2, the plate W_2 constituting one terminal of a circuit which contains the telephone receiver T_2 and current source B_2, the other terminal of said circuit being connected to one side of the filament circuit. One terminal of another circuit is connected to the grid G_2, the other terminal of said circuit being connected to the other side of the filament F_2. This last mentioned circuit is inductively associated with the oscillating circuit which contains the coil P, as for instance, through the coils L_1 L_2, the latter being shunted by a variable capacity C_2. By means of the variable condenser C_2 this secondary system can be accurately attuned to the frequency of the received oscillations. It is obvious that this secondary receiver circuit may be associated with the antenna-earth system, or with the circuit of coil P, in any other suitable or well known manner.

Any suitable means may be employed to supply the necessary inertia to the circuit of battery B, such, for instance, as by including an impedance coil I, in said circuit.

Fig. 2 shows a "balanced antenna circuit" associated with the source of the oscillations S, and its inductances and capacity so proportioned relative to the capacity of the antenna itself that the total effect of the oscillations from the source S upon the receiver transformer L_1 L_2 is neutralized while at the same time impulses received on the antenna S, preferably of a slightly different frequency from that of the oscillations from S_1, are clearly received in the properly attuned receiving circuit L_2 C_2 and transmitted to the audion detector U and translated there into telephone currents in the circuit T B in the well known manner.

I am unable at the present time to give a complete explanation of the theory of action of the apparatus when operating as a generator. I have discovered, however, as hereinabove stated, that a system constructed as shown and described and energized from a suitable current source, becomes the seat of continuous high frequency oscilla-

tions. Undoubtedly the phenomena involved depends upon the effect of successively applied charges or surges of potential upon the grid and plate elements and having the power to effect momentarily the conductivity of the medium between the filament and plate electrodes in such manner that the current variations in the grid filament circuit produce corresponding variations in the plate filament circuit which are fed back to the grid filament circuit to add their effects to the initial variations, which latter, thus reinforced, create and form greater variations in the plate filament circuit which are, in turn, fed back to the grid filament circuit to still further amplify the variations in that circuit, and so on. The energy of the variations of each circuit reacts upon and increases that of the other circuit until a maximum sustained alternating current is finally produced, whose frequency can be controlled by varying the electrical constants of the associated circuits. In other words, the amplifying action incident to the feeding back of energy from the one circuit to the other increases until oscillations are produced which, once set up are self-perpetuating, analogous to the "whistling" or surging action observed when a telephone receiver and microphone transmitter, connected together in the same or coupled circuits, are so placed as to react one on the other mechanically and electrically.

From the foregoing description it will be observed that in its broad scope my invention lies in the discovery that when suitably connected and associated an audion becomes a generator of oscillating, alternating or pulsating electric currents which may be utilized for any purpose for which such currents are desired, and I have succeeded in securing remarkable results in the practical use and operation of an oscillation generator of this character particularly when applied to the generator of high frequency oscillations.

It is obvious that the principles of my invention may be embodied in various other arrangements, and that various changes in the details might readily occur to those skilled in the art, and still fall within the spirit and scope of my invention.

But having now set forth the objects and nature of my invention, and arrangements embodying the principles thereof, what I claim as new and useful, and of my own invention, and desire to secure by Letters Patent, is,—

1. In a system for generating electrical oscillations, a work circuit, and means for generating and transmitting the generated oscillations to said work circuit comprising an evacuated vessel having a hot electrode, a cold plate electrode and a cold grid electrode, an oscillating circuit, one side of said circuit being connected to the grid electrode and the other side to the plate electrode, and means for impressing an electromotive force in the space between the hot electrode and the plate electrode.

2. In a system for generating electrical oscillations, a work circuit, and means for generating and transmitting the generated oscillations to said work circuit comprising an evacuated vessel having a hot electrode, a cold plate electrode and a cold grid electrode, interposed between the hot and cold plate electrode, a source of current for the hot electrode, an oscillating circuit connecting said cold electrodes, and means for impressing an electromotive force between said hot electrode and said cold plate electrode.

3. In a system for generating electrical oscillations a work circuit, and means for generating and transmitting the generated oscillations to said work circuit including an evacuated vessel having hot and cold electrodes therein, circuits for said electrodes, one of said circuits being a series oscillating circuit and connected between said cold electrodes, and means for impressing an electromotive force in the space between two of said electrodes.

4. In a system for generating electrical oscillations a work circuit, and means for generating and transmitting the generated oscillations to said work circuit including an evacuated vessel having hot and cold electrodes therein, circuits for said electrodes, one of said circuits being a series oscillating circuit and connected between said cold electrodes, means for impressing an electromotive force in the space between two of said electrodes, and a telephone associated with one of said circuits.

5. Means for producing high frequency oscillations for transmission comprising a transmitting circuit associated therewith, an oscillatory circuit having two cold electrodes in an exhausted receptacle and a second circuit having a conducting electrode within said receptacle, one of said oscillating circuit electrodes being interposed between the other two, and means for impressing an electromotive force between one of said cold electrodes and said conducting electrode.

6. Means for producing high frequency oscillations for transmission comprising a transmitting circuit associated therewith, an oscillatory circuit having two cold electrodes, a conducting electrode, one of said cold electrodes being interposed between the other two, a circuit connection between the conducting and one of the cold electrodes, and means for varying the frequency of the produced oscillations.

7. Means for producing high frequency oscillations for transmission comprising a transmitting circuit associated therewith, an oscillatory circuit having two cold elec-

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trodes, a second circuit including a current source and a conducting electrode, one of said cold electrodes being interposed between the other two electrodes, and means for producing a flow of current through the space between said electrodes.

8. Means for generating high frequency oscillations for transmission including a transmitting circuit associated therewith, an evacuated vessel containing hot and cold electrodes, and a series oscillation circuit connecting said cold electrodes and a source of power associated with said circuit.

9. Means for generating high frequency oscillations for transmission including an evacuated vessel, a circuit including a transmitting circuit associated therewith, a current source and having its terminals within said vessel and separated from each other, and an oscillatory circuit including a conducting body interposed between said terminals.

10. The combination with a work circuit, and means for generating and transmitting the generated alternating currents to said work circuit, comprising an evacuated vessel having a hot and a plurality of cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, inductance and capacity connected between the cold electrodes, means for impressing electro-motive force in the space between one of the cold electrodes and the hot electrode, and means for supplying current to the hot electrode.

11. The combination with a work circuit, and means for generating and transmitting the generated alternating currents to said work circuit, comprising an evacuated vessel having a hot and a plurality of cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, an oscillating circuit connecting the cold electrodes, means for impressing an electro-motive force in the space between the cold and hot electrodes, and means for supplying current to the hot electrode.

12. An audion having a plurality of grid electrodes, a plurality of wing electrodes, and a hot electrode, a series oscillating circuit associated with the grid and wing electrodes, and means for impressing an electromotive force between the wing and hot electrodes.

13. In a radio signaling system, an evacuated vessel having separate electrodes therein, and circuit connections therefor to constitute a combined generator of high frequency oscillations and detector for high frequency oscillations.

14. In a radio signaling system, an evacuated vessel having separate electrodes therein, and circuit connections therefor to constitute a combined generator of high frequency oscillations and a detector for received high frequency oscillations, and an antenna system associated therewith.

15. In a radio signaling system, an evacuated vessel including hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrodes, circuits connecting each of said cold electrodes to said hot electrode, and means to set up successively increasing potentials in said circuits.

16. In a radio signaling system, an evacuated vessel containing hot and cold electrodes therein, circuits connecting each said cold electrode with said hot electrode, said circuits being associated, a source of electromotive force, and a signal indicating device being included in said circuits, and an antenna system associated with said circuits, and means for operating said signaling system as either a transmitting or a receiving system.

17. In a radio signaling system, an audion including hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, circuits connecting each of said cold electrodes to said hot electrode, and means to cause said circuits to react upon each other.

18. In a radio signaling system, an audion including hot and cold electrodes therein, said cold electrodes being located at relatively different distances from said hot electrode, circuits connecting each of said cold electrodes to said hot electrode, said circuits being associated to react upon each other.

19. In an electrical system, an evacuated vessel, hot and cold grid and plate electrodes therefor, a circuit connecting each of said cold electrodes with said hot electrode, said circuits being associated to react upon one another.

20. In an electrical system, an evacuated vessel, a hot electrode within said vessel, cold grid and plate electrodes associated therewith, a circuit connecting each of said cold electrodes with said hot electrode, said circuits and electrodes being so associated that electrical variations in either circuit produce an electrical variation in the other circuit.

21. In an electrical system, an audion including a hot electrode, a plate electrode and a controlling electrode, circuits connecting the plate electrode and controlling electrode with said hot electrode, and means for causing variations in the circuit of the plate electrode to react upon the controlling electrode.

In testimony whereof I have hereunto set my hand in the presence of the subscribing witnesses, on this 10th day of March A. D 1914.

LEE DE FOREST.

Witnesses:
S. EDWARD [illegible],
W. A. DARBY.

[fol. 3751] IN THE SUPREME COURT OF THE UNITED STATES, OCTOBER TERM, 1942

No. 369

STIPULATION—Filed Jan. 5, 1943

It is hereby stipulated and agreed by and between counsel for the respective parties herein, subject to the approval of the Court, as follows:

(1) That the following and only the following exhibits shall be printed or reproduced for use on the argument of the above-entitled cause:

Plaintiff's exhibits: Nos. 7; 19; 20; 21; 22; 34; 35; 36; 46; 53; 59; 60; 69; 72; 74; 75; 77; 78 (1913 edition; Figs. 29a, 31, 33, 62, and 89; 1915 edition: Figs. 84 and 88); 79; 80; 84; 87; 91 (Figs. 36 and 37); 92 (Figs. 1, 3, 4, 6, 9, and 61; and page 110); 95; 99; 102; 103; 106; 107; 108; 109; 110; 111; 112; 113; 114; 116; 120′ (Interdepartmental Radio Board Preliminary Report); 120″ (Stone Canadian Society Lecture); 121′ (Stone U. S. Patent No. 767,984); 121″ (Interdepartmental Radio Board's Letter of April 16, 1921); 122; 142; 150; 151; 157; 158; 159; 160; 171; 2 3 (Fig 45); 205 (Fig. 218; 211; 223; 225; 227; 228; 229; 230; 241; 242; 243; 244; 246; 248 (Figs. 2, 3, 4, and 5); 250; [fol. 3752] 258; 259; 260; 261; 262; 263; 264; 265; 266; 268; 269; 270; 273; 274; 275; 276; 282; 287; 289; 290; 298; 300; 301; 302; 315; 317; 318; 319; 322; 323; 324; 325; 326; 327; 335; 343; 344; 347; 348; 349; 363; 364; Waterman's Drawings Nos. 1, 2 and 3; 410; 413A; 419; 420; 440; 441; 453; 454; 455; 462; 472; 477A. (Note that 477A is the same as part of the April 6, 1942 findings of the Court of Claims and appears at page 142 of the printed record.)

Defendant's exhibits: Nos. A; B; C; D; I; J; K; L; M; N; O; P; S; T; U; V; W; X; Z; A-1; B-1; C-1; D-1; E-1; F-1; G-1; H-1; I-1; J-1; K-1; L-1; M-1; N-1; P-1; T-1; A-2; B-2; C-2; E-2; F-2; M-2; O-2; P-2; Q-2; R-2; U-2; V-2; W-2; X-2; Y-2; Z-2; A-3; B-3; D-3; E-3; F-3; G-3; H-3; I-3; K-3; N-3; P-3; Q-3; R-3; B-4; E-4; J-4; R-4; S-4; Z-4; A-5; B-5; C-5; D-5; E-5; F-5; G-5; N-5; O-5; Q-5; S-5; T-5; U-5; V-5; W-5; X-5; B-6; L-6; M-6; N-6; Q-6; S-6; V-6; W-6; Y-6; Z-6; JJ; KK; LL; MM; PP; BBB and UUU. (As to KK, it will be sufficient to note

that it is the same as Defendant's Exhibit U-2 to be reproduced. As to LL, Fessenden patent 706,735, it will be sufficient to reproduce it as part of Plaintiff's Exhibit 171 and note that LL is the same as such part of Exhibit 171.

(2) Whereas, through inadvertence, page 73 of plaintiff's exhibit No. 92 was included in the transcript of record certified to this Court from the Court of Claims herein instead of page 75 thereof, it is further stipulated and agreed that the annexed copy of Fig. 62 of said exhibit (the same being a part of said page 75) shall be reproduced as a part of the record herein in lieu of Fig. 60 (which was a part of the erroneously-included page 73 of the said exhibit); and it is further stipulated and agreed [fol. 3753] that said Fig. 62 of said exhibit was a part of the printed record that was before the Court of Claims herein, and that certification thereof is therefore hereby waived.

Dated: December 31, 1942.

Richard A. Ford. Abel E. Blackmar, Jr., Counsel for Petitioner. Charles Fahy, Solicitor General of the United States. Clifton V. Edwards, Special Assistant to the Attorney General.

[fol. 4133] IN THE SUPREME COURT OF THE UNITED STATES, OCTOBER TERM, 1942

No. 369

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA

v.

UNITED STATES

STIPULATION AND ADDITION TO RECORD—Filed March 29, 1943

It is hereby stipulated between the respective parties by their attorneys, this Honorable Court consenting, that the attached reproduction of Defendant's Exhibit P-1 is a true copy of the said translation as it appeared in the printed record in the Court of Claims proceedings as to which certiorari has been granted, the illustrations in said attached reproduction having been inadvertently omitted in the transcript of record certified to this Court.

It is stipulated that the attached copy may be considered with like force and effect as though it were included in the printed transcript at the place designated, and that copies of said attached translation including the drawings may be substituted in lieu of the copy of said translation now appearing in Volume V, pages 3515-3518.

Dated March 23, 1943.

Abel E. Blackmar, Jr., Counsel for Petitioner.
Charles Fahy, Solicitor General of the United States.

1 **DEFENDANT'S EXHIBIT P 1**

(Translation of Defendant's Exhibit O-1). Physikalische Zeitschrift--Oct. 20, 1904, pp. 680-81. "Translation of Wehnelt article

A Wehnelt (Erlangen), in Reference to the exit of Negative Ions from Incandescing Metallic Oxids and Phenomena Connected Therewith"

In a treatise with the same heading in Vol. 14, pp. 425-468 of the Annalen der Physik (1904) I have set forth a series of experiments and measurements which showed that certain metallic oxids, and in fact, especially the oxids of the earth alkali metals in an incandescing state, both under atmospheric pressure and also in a vacuum, emit numerous negative ions. (electrons)

[1] Read in Division 2 on the 21st of Sept. Exhaustive literary references are to be found in Annalen der Physik Vol. 14, p. 425-468, 1904.

[1a] Vorgetragen in Abteilung 2 am 21. Sept. Ausführliche Litteraturangaben befinden sich Annalen der Physik 14, 425-468, 1904.

In intimate connection with this quality stands the fact also discovered by me, that the cathode drop in a glimmer charge completely disappears on glowing oxid cathodes even under the deepest pressures, provided that the current density (current strength per square centimeter of incandescing oxid surface) remains below a value depending upon the temperature and increasing with this. That current density at which a cathode drop begins to show I have called the limit current density. It attains, under high incandescence of the oxid, values up to three amperes.

I wish today to first bring before you some experiments which explain that which has been said above, and then to show you a practical application of incandescing oxid cathodes.

Emission of Negative Ions by Incandescing Metallic Oxids.—A glass tube R (Fig. 1), exhausted to a moderate extent contains a brass cylinder C in the axis of which there is situated a thin platinum wire D covered with CaO. The wire can be heated to high temperatures by the current of two accumulators A.

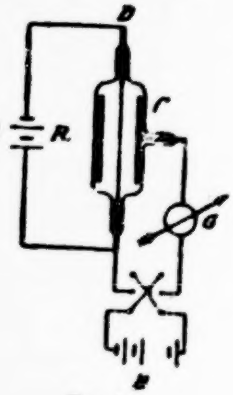

Fig. 1.

If I connect the wire D with the one pole, the cylinder C through a galvanometer G with the other pole, of a source of current B, then there only flows a current through the tube if D is connected with the negative pole of B. The experiment shows consequently that only negative ions are emitted from the incandescing oxid.

If I take another tube, which is otherwise exactly similar, but which contains a platinum wire carefully cleaned, and heat the same to the same temperature as previously the wire covered with CaO, then the current is under an equally high negative charge of the wire only exceedingly weak, and in fact, only about 1/1000 of that in the former experiment.

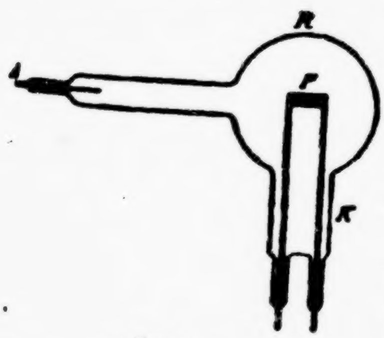

Fig. 2.

Incandescing Metallic Oxids as Cathodes in Discharge Tubes.—The tube R (Fig. 2) contains as cathode K a platinum sheet P covered with CaO which can be electrically heated red hot, and as an anode an iron wire A. The surface of the incandescing metallic oxid cathode amounting to several square centimeters, allows of sending through the tube considerable current strengths, even under deep pressures without there being present a cathode drop.

Since the anode drop constantly amounts to about 20 volts and the drop on the positive cells under strong currents and low pressures, as special measurements have shown, amounts to only one to two volts per centimeter, I can, by using the light conductor of

220 volts potential, send through the tube (Fig. 2) currents of severa amperes strength. The incandescing oxid cathodes furnish us conse quently with a means of investigating the processes in the positive column with any gas whatever and under any pressures however deep, up to very high current strengths. The remarkable brightness of the positive strata under high current strength promises to be
serviceable to the spectro-analytical investigation of gas spec-
3 tra. Quartz windows on the tube would also make the
ultra violet portion of the light of the strata accessible to
investigation.

Weak Cathode Rays.—If we exceed the limit current density eith by increasing the current strength or decreasing the temperature the incandescing oxid cathode, then we can impart to the cathode drop any desired value, and consequently produce cathode rays of any desired velocity.

The tube, Fig. 3, contains as cathode K a small platinum sheet P upon which there is located a small speck of calcium oxid.

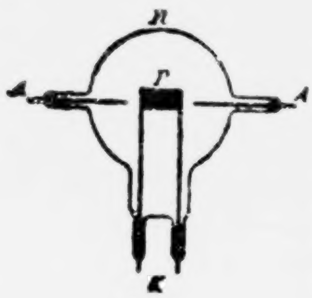

Fig. 3

A brass rod A serves as anode. If the she P is electrically brought to a glowing heat an the electrodes A, K, by throwing in a suitab resistance are connected with the light co ductor of 220 volts potential, then the entire current goes only through the calcium ox coating on the cathode sheet P, since here the cathode drop is much lower than on the clea platinum sheet, whereby there proceeds an intensely blue cathode beam of rays from the coating. By changing the temperature of the platinum sheet, there can be imparted to the cathode rays then any desired velocity, and this can then be measured according to we known methods.

Application of Discharge Tubes with Glowing Metal Oxid Cathode
Practice.—If in an exhausted discharge tube R (Fig. 4[1]) we
4 push one or several metallic electrodes A close to the glowing
metallic oxid electrode K (platinum sheet P covered with Ca0)
then the discharge potential, if A is anode and K is cathode, amounts to only about twenty volts. If we reverse the direction of current so that now A is cathode and K is anode, the discharge potential now amounts to some thousands of volts, since under deep pressures the cathode drop on metals takes on exceedingly high values. If, there fore, we connect the electrodes A and K with an alternating source of current, the potential of which lies below the value which the cathode drop on the metallic electrode A has, then the tube acts as an electric valve, in that it allows to pass through only one phase of the alternating current. The tube (Fig. 4) can consequently serve for the pur pose of transforming alternating current into pulsating direct current

[1] The cathode K is assumed to be turned 90° as regards the plane of the picture.

The maximum current strength to be sent through the tube (valve ...e depends as follows, from what has been said above, upon the ... of the glowing oxid surface. The efficiency of the valve tube ...ends upon the working potential employed, and ...reases with this, since the tube up to the strongest ...wable current strength, entirely independent of ...is absorbs always only 20 volts potential. In ...plying a working potential of 120 volts alternating ...rent, taking into consideration the consumption ... watts for heating of the metal oxid cathode, the ...ciency of the valve tube amounted to about 65%.

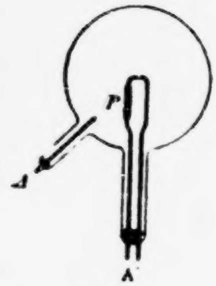

Fig. 4

By using the well-known Graetz system of con...ction both phases of the alternating current can ...utilized. By using three metallic anodes, we ...as with a Hewitt transformer, also transform rotary current into ...sating direct current.

Discussion